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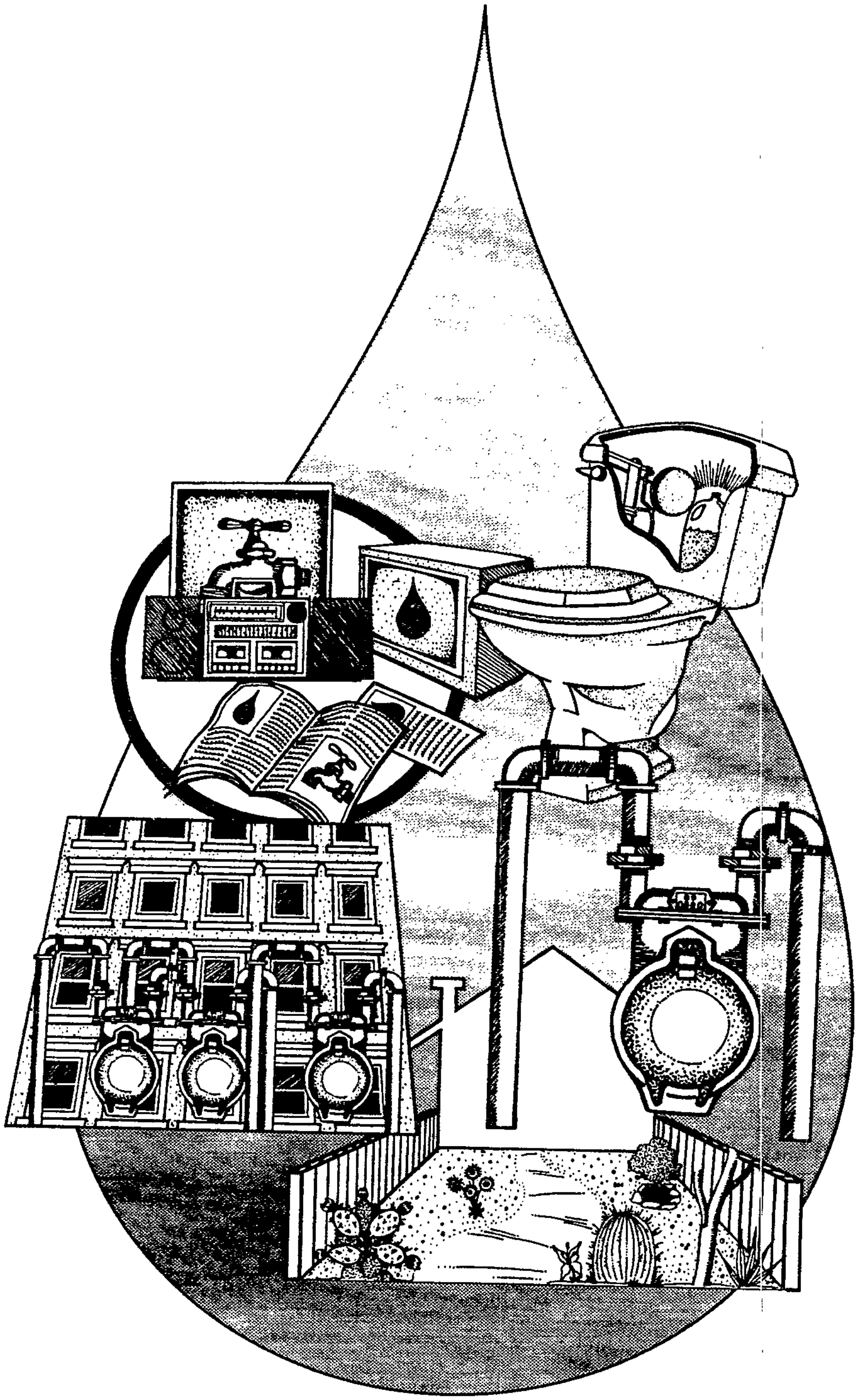
Cleaner Water Through Conservation



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Office of Wetlands, Oceans and Watersheds
401 M Street, SW
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Rod Frederick	OWOW Nonpoint Source Control Branch
Dov Weitman	OWOW Nonpoint Source Control Branch
Steve Dressing	OWOW Nonpoint Source Control Branch
Joan Warren	OWOW Policy and Communications Staff
Marilyn Ginsberg	Office of Drinking Water and Ground Water
Steve Clark	Office of Drinking Water and Ground Water
David Rathke	USEPA Region 8
John Flowers	Office of Wastewater Management
Bill Swietlik	Office of Wastewater Management
Jocelyn Woodman	Office of Pollution Prevention
Julie Winters-Lynch	Office of Pollution Prevention

Dr. John Hochheimer directed the project for Tetra Tech and was assisted by Shannon Cauley, Chelie Billingsley, Jana Suchy, Sam Pett, and George Townsend. Martha Martin provided editorial support, and Robert Johnson, Kelly Gathers, and Nathan Hearn provided production and graphics support.

Introduction

When More Is Better

The recognition of diffuse, or nonpoint source, pollution as a major contributor to declining water quality has spawned another approach to improving our water resources: better water quality through greater water quantity.

This document explains the relationship between the quantity of water and its quality and discusses how developing water-use efficiency programs can help states and local communities achieve cleaner water through conserving water.

Conserving water can actually improve water quality.

Typically, nonpoint source (NPS) pollution originates from rain and melted snow flowing over the land, which is called runoff. As runoff contacts the land's surface, it picks up many pollutants in its path—sediment, oil and grease, road salt, fertilizers, pesticides, nutrients,

toxics, and other contaminants. Runoff can also originate from irrigation water used in agriculture and on landscapes. Many pollutants are picked up by irrigation water as it runs off the land.

Water conservation coupled with pollutant source reduction, such as nutrient and pesticide management, would be a particularly effective approach to reducing the adverse effects of all types of NPS pollution. The focus of this document, however, is on the types and sources of NPS pollution most commonly associated with urban uses of water.

Other types of nonpoint pollution include changes to the natural flow of water in stream channels or wetlands. Changes to the natural flow of water in streams or wetlands result in habitat destruction for fish and wildlife. Placing dams across our rivers and streams can permanently alter the characteristics of upstream and downstream areas by flooding upstream habitats and drying downstream habitats. Failures of onsite disposal systems (septic tanks) lead to increases in nutrients, harmful bacteria in oyster and clam beds, and closures of public swimming areas. Conserving water can help to reduce some impacts from these other sources of nonpoint pollution.

Perhaps most relevant, however, besides the intrinsic benefit of improving water quality by addressing water quantity, are the other, economically beneficial effects of these water quality improvements. Some of the NPS pollution problems that can be *reduced* by improved water conservation include:

- On-site disposal system failures
- Dried-up downstream wetlands
- Polluted runoff from overirrigation of agricultural and urban lands
- Construction of additional dams and reservoirs and additional water and wastewater treatment facilities
- Surface water withdrawals that result in habitat degradation both instream and on land adjacent to streams and lakes (*riparian* areas).

The many benefits of water use efficiency include cost savings and pollution prevention even beyond nonpoint source pollution because many pollution prevention practices and activities result in reduced water use, which saves money. However, some pollution prevention practices that do not reduce NPS pollution also provide a cost savings, making these three driving forces (water use efficiency, cost savings, and pollution prevention) great companions. The umbrella term "water use efficiency" actually defines a larger area of two subcategories: water conservation—finding ways to use less water to begin with—as distinct from water *reuse* and *reclamation*, such as "closed loop cycles" to reuse water in commercial and industrial settings or use of partially treated wastewater for lawn watering and in industrial settings.

Implementing practices or programs outlined in this guide might help reduce onsite disposal system failures and decrease runoff of nutrients and soil from landscaped areas or agricultural fields. By reducing septic system failures and conserving irrigation water, we can also protect ground water from nitrates and salinity to preserve and safeguard our drinking water supplies.

Similarly, saving water through improved efficiency can lessen the need to withdraw ground or surface water supplies for municipal or industrial demands. Conserving water decreases the need to impound or otherwise regulate the natural flow of streams, thus preserving free flow to retain the value of stream and river systems as wildlife habitat and for tourism and recreation.

Conserving water reduces the need to impound streams = preserved free flow + retained value for habitat, tourism, and recreation.

In addition, building fewer and smaller new water projects can help prevent the destruction or degradation of pollutant-filtering wetlands. Efficient water use can also mean a reduction in the amount of energy needed to treat wastewater, resulting in less energy demand and therefore fewer by-products from power plants.

The reuse of wastewater or reclaimed water is beneficial because it reduces the demands on available surface and ground waters. Also, recycling process water can reduce industrial pollutants discharged into lakes, streams, rivers, and oceans. Perhaps the greatest immediate benefit of establishing water reuse programs is their contribution to delaying or eliminating the need to expand potable water supply and treatment facilities. However, sometimes this reuse can also adversely impact waters. Highest quality water sources are preserved for drinking water by using treated wastewater for other uses (USEPA, 1990e).

Water conservation is not a new idea in the United States. In fact, more than 40 states now have some type of water conservation program. Nationwide surveys already indicate more than 80 percent of water utility customers support some form of water conservation measure (Kranzer, 1988). Water suppliers and consumers can choose from a wide variety of available water conservation practices, programs, and strategies proven capable of significantly reducing water consumption. These include:

- Metering
- Reducing water pressure
- Imposing water use restrictions
- Enacting zoning ordinances
- Changing price structures
- Educating the public.

Water suppliers include municipalities and local and state governments.

The Snake

In some areas of the country, such as the Snake River in Idaho, water demands are so great during summer months that all incoming river water at a water supply reservoir is needed to provide for the demand.

Because water is not passed through or over dams at these supply reservoirs, one source of the natural supply to downstream areas is cut off although all water withdrawn from these heavily used rivers is not consumed and some returns to the river via wastewater treatment outfalls, irrigation return flows, and industrial discharges. These returns are combined with flows from springs to provide water for downstream uses, but often at levels significantly below those needed to sustain instream and riparian habitat.

In other areas, such as arid Arizona, ground water withdrawals exceed recharge and water is therefore mined without replacement.

So What?

Low-flow toilets currently in use throughout Texas could reduce the need to build new water and wastewater treatment plants by 15 percent and result in savings of as much as $68 million per year. Residential water and sewer bills could also be reduced by as much as $200 million over the long term.

The Texas Water Development Board estimates that the use of water-efficient plumbing fixtures should save a typical four-member household 55,800 gallons of water and $627 in lower water and energy (i.e., water heating and pumping) costs per year. The Board also projects that the use of low-flow fixtures might reduce water use statewide by 805 million gallons per day by the year 2040 (Jensen, 1991).

This document is designed to serve as both resource and guide for state and local officials, particularly where water conservation is determined to be an important consideration in protecting water quality. *A Guide to Cleaner Water Through Conserving Water* begins with a review of water use in the United States, showing trends in major categories of water use. The second chapter outlines a variety of nonpoint pollution impacts resulting from excessive water use, and the third chapter describes some of the technical and programmatic approaches available to reduce water use and thus protect water quality. The fourth chapter provides a number of examples of regional programs implementing many of these approaches. The document concludes with a glossary and references to aid in understanding the material.

Perspective

Even seemingly small levels of water conservation and use efficiency have the potential to reduce nonpoint source pollution at the local level.

For instance, an example described in Chapter 2 tells of a section of the Buffalo River in Henry's Fork, Idaho, where a massive die-off of wintering trumpeter swans occurred due to the combination of very cold weather and reduced flows resulting from the construction of a dam. A subsequent study determined that a minimum flow of 500 cubic feet per second (ft^3/s) is necessary to sustain the population of swans as well as the fishery (USDOI, 1992).

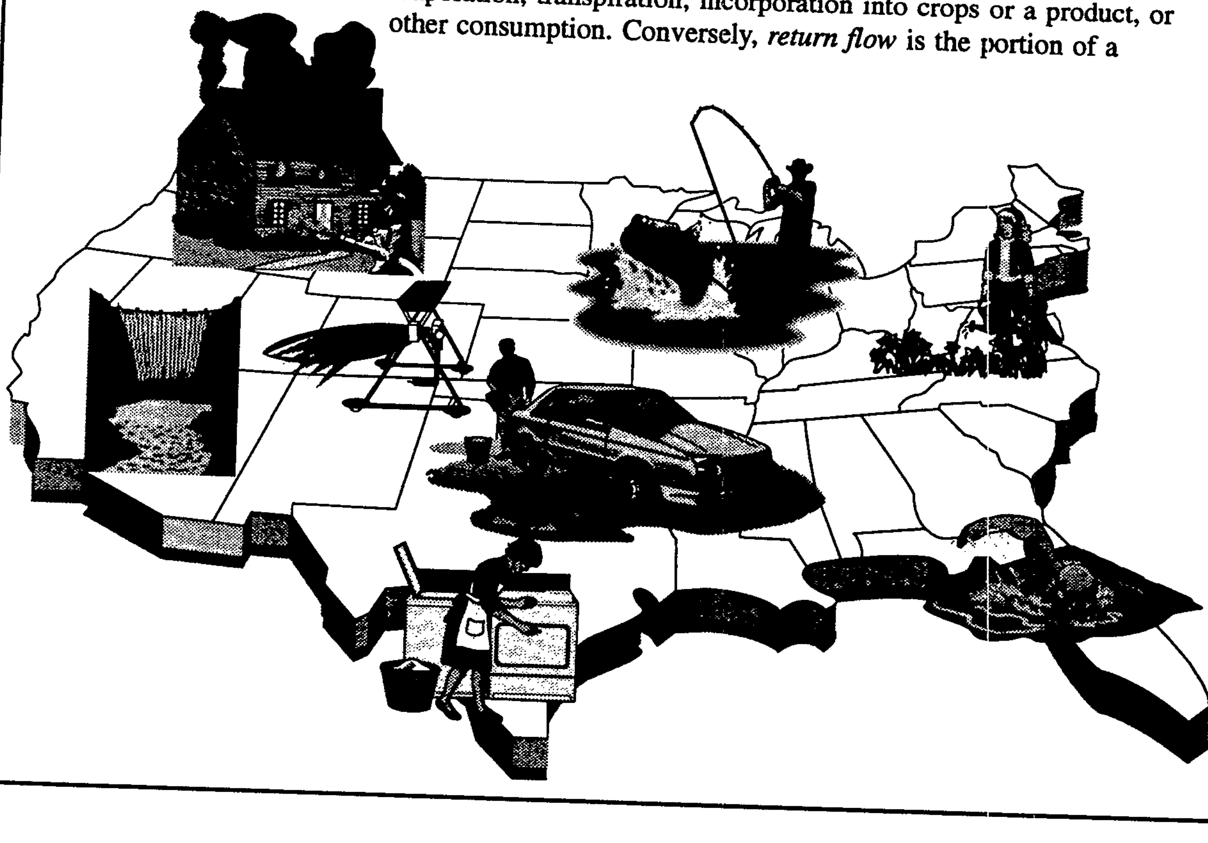
Examples of water conservation methods that could conserve this much flow include:

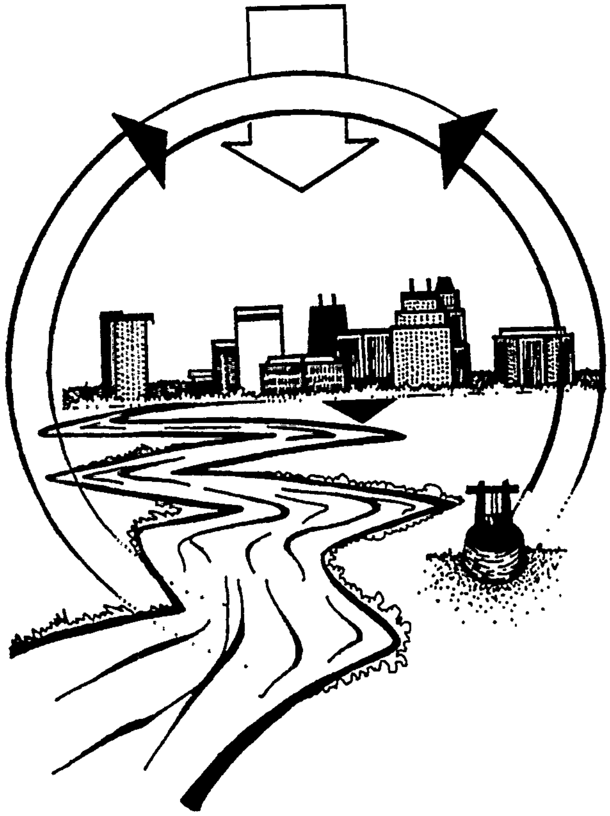
- A flow of 500 ft^3/s is roughly the equivalent of the water savings from 9 days of water-use reductions if all toilets in the Boston area were converted from conventional to low-flush units.
- Capping all the abandoned wells in Seminole County, Florida, would save this same volume of flow in a little less than 6 days.
- And on a larger scale, if the Texas Water Development Board meets its goal of converting all plumbing fixtures in the state to water-conserving fixtures, then this volume could be saved in *less than10 hours.*

Chapter 1

How We Use Water in These United States

Water use is usually defined and measured in terms of *withdrawal* or *consumption*—that which is taken and that which is used up. Withdrawal refers to water extracted from surface or ground water sources, with consumption being that part of a withdrawal that is ultimately used and removed from the immediate water environment—whether by evaporation, transpiration, incorporation into crops or a product, or other consumption. Conversely, *return flow* is the portion of a





Withdrawal, consumption, and return flow of water from surface water and ground water sources.

withdrawal that is actually not consumed, but is instead returned to a surface or ground water source from a point of use and becomes available for further use.

Water Withdrawal = Consumption + Return Flow

Water use can also be divided into *offstream* and *instream* uses. Offstream water use (see Table 1) involves the withdrawal or diversion of water from a surface or ground water source for

- Domestic and residential uses
- Industrial uses
- Agricultural uses
- Energy development uses.

Instream water uses are those which do not require a diversion or withdrawal from the surface or ground water sources, such as:

- Water quality and habitat improvement
- Recreation
- Navigation
- Fish propagation
- Hydroelectric power production.

National Trends in Water Use

National patterns of water use indicate that the largest demand for *water withdrawals* (fresh and saline) is for thermoelectric generation (47 percent), followed by irrigation (34 percent), public supply (9 percent), industrial (6 percent), mining (1 percent), live-stock (1 percent), domestic (1 percent), and commercial uses (1 percent) (Solley et al., 1993). While thermoelectric generation represents the largest demand for fresh *and* saline withdrawals, irrigation represents the largest demand for freshwater withdrawal alone (see box page 7). Activities that reduce the need to withdraw surface and ground water will lead to many of the beneficial effects of conserving water.

National Consumption Patterns

Water consumption varies by water use category, with irrigation consuming the highest per-

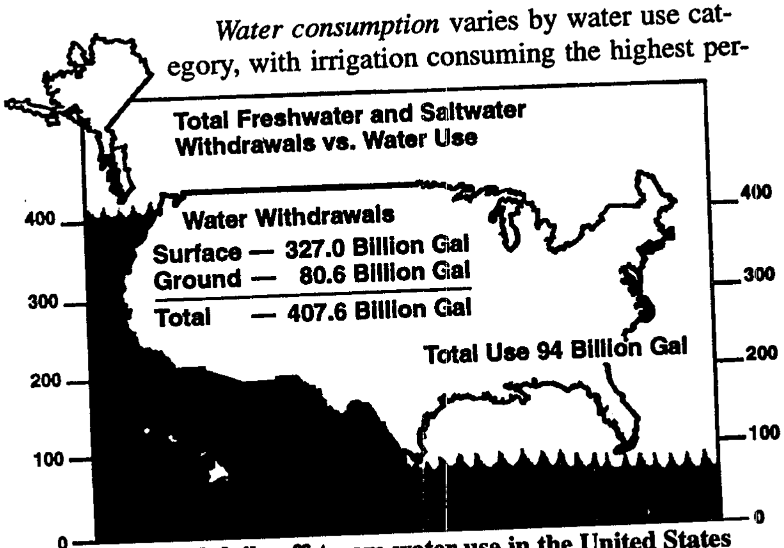


Table 1. Total daily offstream water use in the United States (Solley et al., 1993).

cent (81 percent) and commercial the lowest (1 percent) (see figure). The difference between the volume of water withdrawn and that consumed is the *return flow*. As more good-quality water is available in return flows, more water is available for other beneficial uses.

Some categories of water use, such as irrigation and livestock watering, consume a high percentage of water that is withdrawn from surface and ground water sources. Thus, less water is available for return flows from these high-consumption activities. Other categories of use like thermoelectric power consume only a small fraction of the water they withdraw.

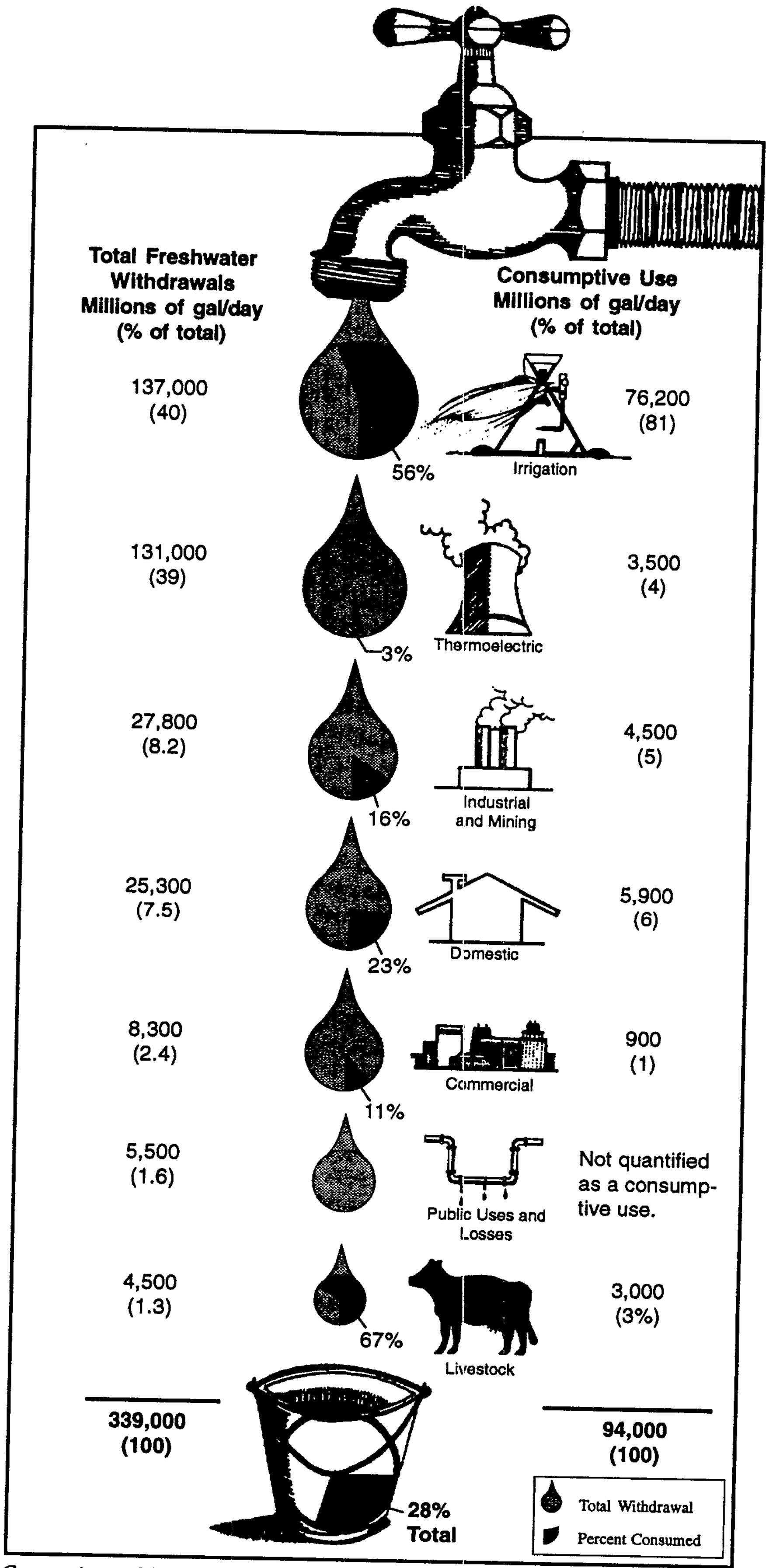
Categories of Water Use

With several different ways to categorize water use in the United States, this chapter separates offstream uses into

- Municipal/public supply
- Domestic and commercial
- Industrial and mining
- Agricultural
- Thermoelectric power.

Municipal/Public Water Supply

While water withdrawals for public use can be applied to street cleaning, fire fighting, municipal parks, and public swimming pools, keep in mind that municipalities and private suppliers might also provide wa-



Comparison of freshwater consumptive use in the United States for 1990, by category (Solley et al., 1993).

ter for other purposes—domestic/commercial, agricultural, thermoelectric power (see Table 2).

Per capita (per person) use of public water supplies in the United States (1990) averaged 183 gallons per day (gal/d). The average per capita use can vary greatly between communities for any number of reasons, including, but not limited to:

- Climate differences
- The mix of domestic, commercial, and industrial uses
- Household sizes
- Lot sizes
- Public uses
- Income brackets
- Age and condition of distribution system.

For instance, per capita use of public water is about 50 percent higher in the West than the East mostly due to the amount of landscape irrigation in the West (see map, p. 9). However, per capita use can also vary greatly within a single state. For example, in 1985 the demand for municipal water in Ancho, New Mexico, totaled 54 gallons per capita per day (gal/cap/day) while in Tyrone, New Mexico, municipal demand topped off at *423* gal/cap/day (Grisham and Fleming, 1989). Rural areas typically consume less water for domestic purposes than larger towns.

In 1990, water withdrawn nationwide for public supplies totaled 38,530 million gallons per day (Mgal/d) (Table 2). Although this withdrawal rate represents a 5 percent increase over 1985 amounts, the number of people supplied with water distributed through public systems also increased 5 percent during that same 5-year period. Again in 1990, surface water supplied about 61 percent of the public water supply, with ground water supplying the other 39 percent (Solley et al., 1993).

Table 2. Fate of Water in Public Water Supplies of the U. S., 1990.

Receiving Category	Volume (Mgal/Day)	Percentage of Total
Domestic	21,900	57
Commercial	5,900	15
Public Use Losses	5,460	14
Industrial	5,190	13
Thermoelectric Power	80	<1
Total	**38,530**	**100**

Of the total water withdrawn in 1990 for public supplies—representing 11 percent of *total* U.S. offstream freshwater withdrawals—72 percent went to domestic and commercial uses, 13 percent to industrial uses, and 0.2 percent to thermoelectric power. The remaining 14 percent went to public uses such as fire protection or was lost during distribution (usually due to leaks).

Domestic/Commercial

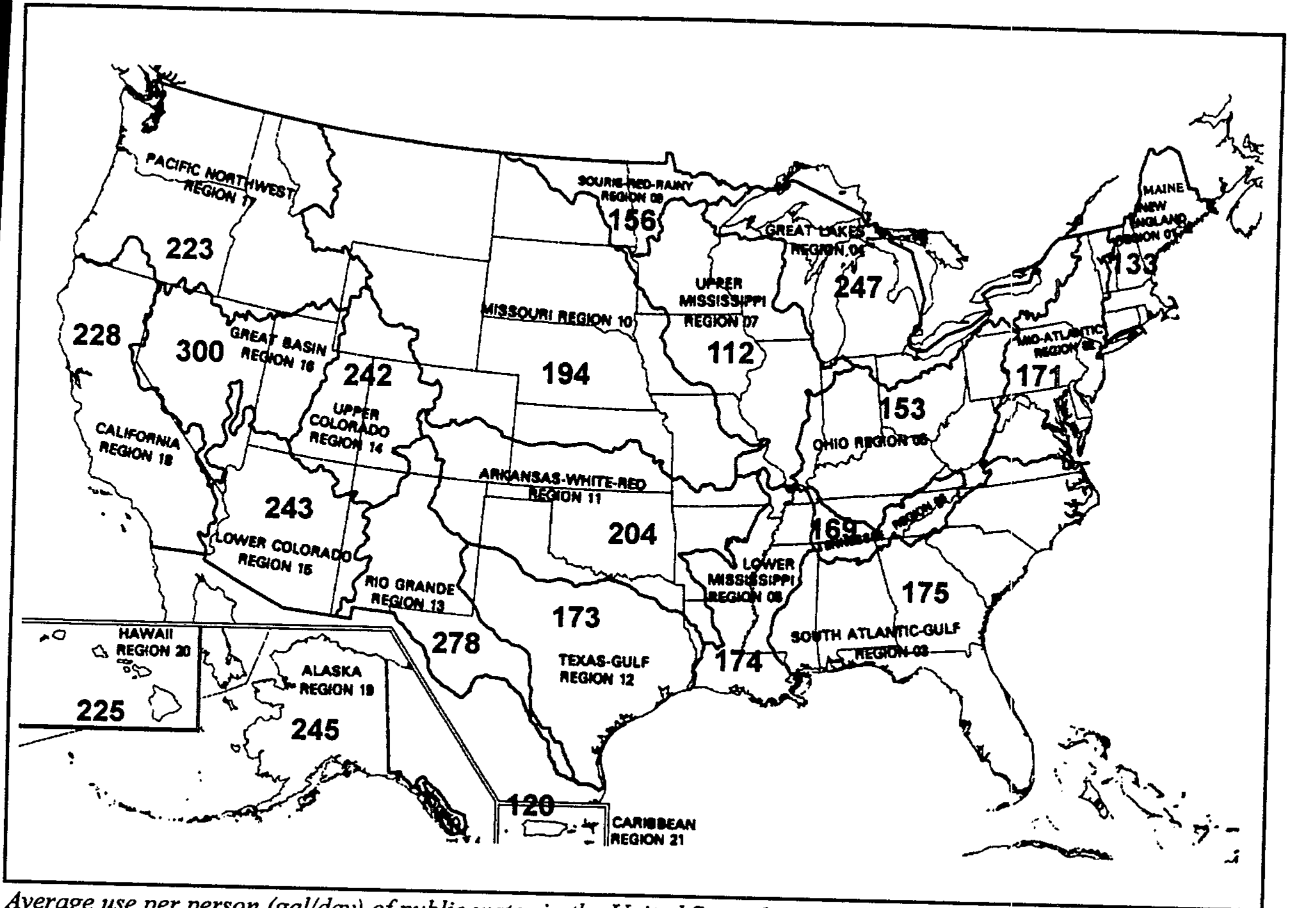
Domestic water use includes everyday uses that take place in residential homes, whereas commercial water uses are those which take place in office buildings, hotels, restaurants, civilian and military institutions, public and private golf courses, and other nonindustrial commercial facilities. Combined freshwater withdrawals for domestic and commercial use in 1990 totaled 33,600 Mgal/d, or 10 percent of total freshwater withdrawals for all offstream categories (see box page 7).

Typical categories of residential water use include normal household uses such as

- Drinking and cooking
- Bathing
- Toilet flushing
- Washing clothes and dishes
- Watering lawns and gardens
- Maintaining swimming pools
- Washing cars.

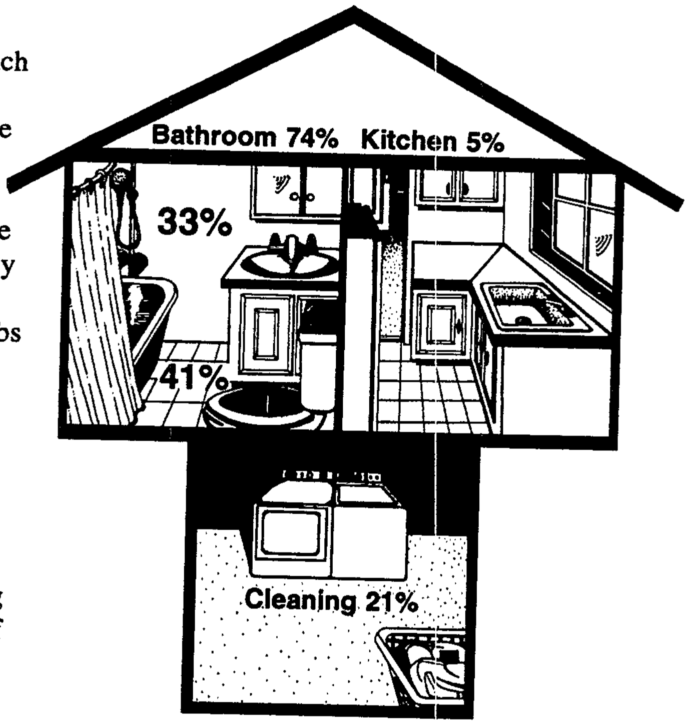
When divided into indoor uses and outdoor uses, the amount of indoor water use remains fairly constant throughout the year, with the breakdown of typical indoor water uses depicted on page 9. By far the largest percentage of indoor water use occurs in the bathroom, with 41 percent used for toilet flushing and 33 percent for bathing (USEPA, 1992).

Outdoor residential water use, however, varies greatly depending on geographic location and



Average use per person (gal/day) of public water in the United States by USGS water region (Solley et al., 1993).

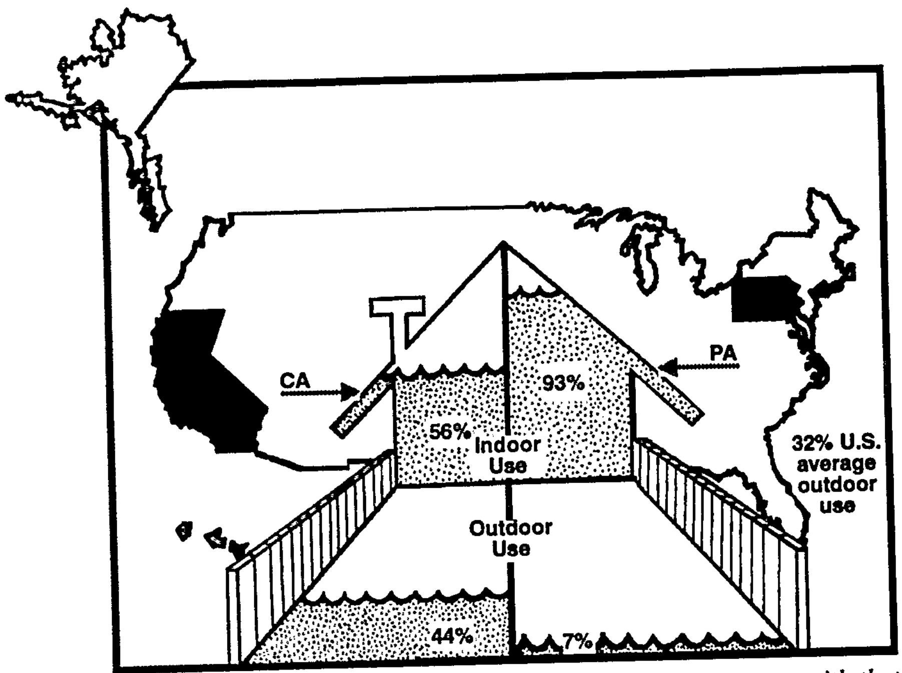
season. On an annual average basis, outdoor water use in the arid West and Southwest is much greater than that in the East or Midwest. The figure on page 10 compares the national average for residential outdoor water use with that of Pennsylvania and California, with landscape irrigation the primary application. While average outdoor water use in Pennsylvania represents only approximately 7 percent of the total residential demand, in California average outdoor use climbs to about 44 percent of the demand.



Typical breakdown of interior water use.

Industrial and Mining

Industrial water uses, estimated to be 8 percent of total freshwater use for all offstream categories, include cooling in factories and washing and rinsing in manufacturing processes. Some of the major water-use industries include mining, steel, paper and associated products, and chemicals and associated products.



Comparison of average national residential outdoor water use with that of Pennsylvania and California (USEPA, 1992).

Water for both industrial and mining uses comes from public supplies, surface sources, and ground water. During the 5-year span from 1985 to 1990, industrial water use in the United States decreased approximately 13 percent. In the same period, mining water use increased about 24 percent (Solley et al., 1993).

Agricultural

Agricultural water use can be divided between irrigation and livestock. Irrigation includes all water applied to farm or horticultural crops; livestock incorporates water used for livestock, dairies, feedlots, fish farms, and other farm needs.

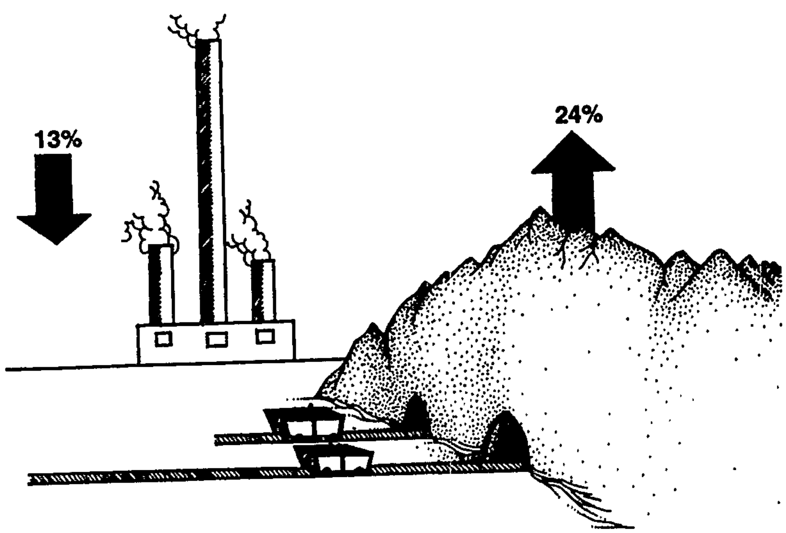
Estimated annual water use for irrigation remained at about the same level between 1985 and 1990, with approximately 63 percent of the water used for irrigation in 1990 coming from surface water. Approximately 60 percent of the water used for livestock came from ground water sources and the remaining 40 percent from surface water sources. Combined water use for irrigation and livestock represents about 41 percent of total offstream freshwater use for 1990, (see figure page 7) with 40 percent going to irrigation and the lone 1 percent to livestock uses.

Not only can the loss of water from irrigation conveyance systems be significant, but the percentage of consumptive water use for agriculture is high as well—an estimated 54 percent consumption in 1985. By 1990 this had climbed to an estimated 56 percent consumption for irrigation uses and 67 percent for livestock uses (see figure page 7).

Thermoelectric Power Generation

This final category includes water used for the production of energy from fossil fuels, nuclear energy, or geothermal energy. Most water withdrawn for thermoelectric power production is used for condenser and reactor cooling. While 1990 estimates of freshwater withdrawals remained constant from 1985, nearly half again as much saline water was also used.

More than 99 percent of the water used for thermoelectric power production comes from



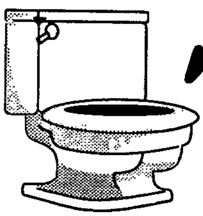
Change in water use 1985-1990.

self-supplied surface water, less than 0.2 percent from public supplies. In 1990, water used for thermoelectric power production represented close to 39 percent of total offstream freshwater use in the United States, but only about 3 percent was consumed (Solley et al., 1993).

The Mid-Atlantic, South Atlantic Gulf, Ohio, and Great Lakes water resource regions use the largest amounts of water for thermoelectric production. The eastern United States uses about five times more water than the West to produce about twice as much thermoelectric power (Solley et al., 1993).

Chapter 2

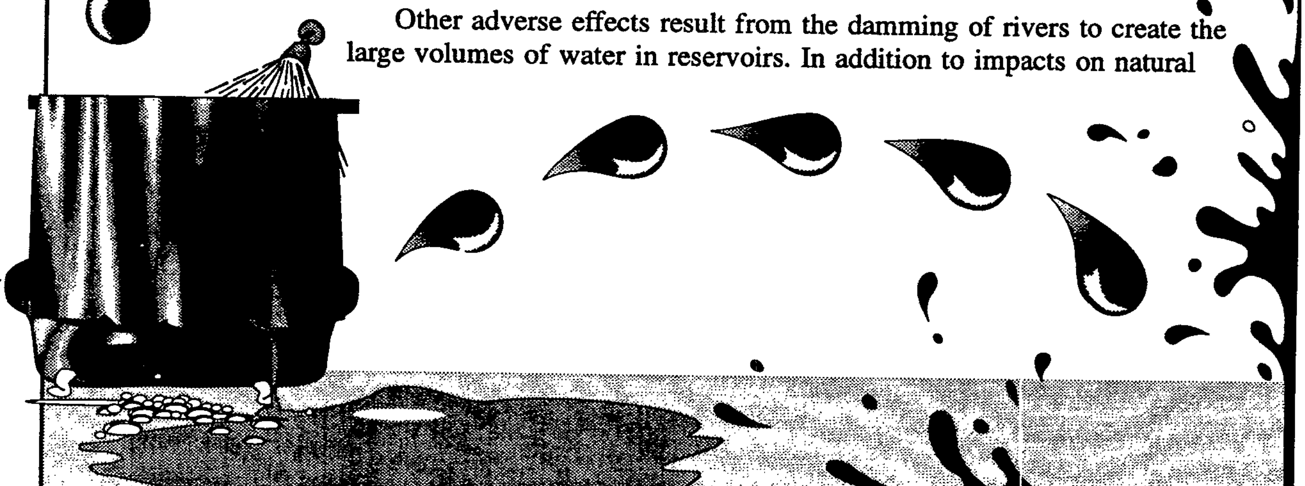
How Excessive Water Use Affects Water Quality



The demand for water in the United States necessitates stream and river impoundments, the drilling of more and deeper wells, and water withdrawals from most natural waterbodies across the country. The high demand for and overuse of water can contribute markedly to nonpoint source pollution in various forms, including:

- Altered instream flows due to surface withdrawals.
- Saltwater intrusion due to excessive withdrawals.
- Polluted runoff resulting from the excess of water applied for irrigation and landscape maintenance that carries with it sediments, nutrients, salts, and other pollutants.

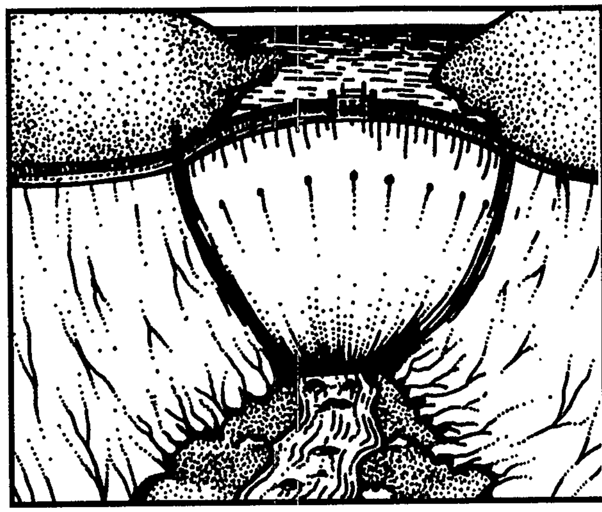
Other adverse effects result from the damming of rivers to create the large volumes of water in reservoirs. In addition to impacts on natural



High demand for and overuse of water contribute to NPS pollution.

habitats, dams themselves create several forms of nonpoint source pollution due to their effects on physical and chemical water quality degradation both upstream and downstream. These NPS impacts are discussed further in the following sections.

Developing New Water-Supply Reservoirs



Building dams to develop new reservoirs can both generate and release a multitude of nonpoint source pollutants both upstream and downstream from the dam. Therefore, to protect water quality, dam construction should be avoided wherever possible. Pollutants include not only suspended sediments, but also pesticides, petrochemicals, solid wastes, construction runoff, and concrete washwater. Impacts from these NPS pollutants can cause any number of problems, including changes in water temperature, dissolved oxygen values, salinity, turbidity, habitat, and living resources. Although these pollutants can cause severe water quality problems in the immediate area of construction, as well as in downstream waterbodies, reservoir construction projects located directly alongside streams and rivers further increase the likelihood of construction-related pollutants entering waterbodies.

The siting of dams can lead to the loss of habitat re-sulting from the inundation of wetlands, riparian ar-eas, and farmland in upstream areas of the impounded waterway, or erosion of these resources in downstream areas. As dams trap sediment and other pollutants, changes in water quality—especially in tailwaters and downstream areas—occur. They include:

- Reduced sediment delivery
- Decreased dissolved oxygen
- Altered temperature regimes
- Increased levels of some pollutants, such as hydrogen sulfide, nutrients, and manganese.

Once streams are impounded, water demand dictates the artificial regulation and control of streamflow. The new flow rates and volume often do not reproduce natural conditions preceding the impoundment. Releases of impounded water with decreased levels of dissolved oxygen, high turbidity, or altered temperature can reduce downstream populations of

Where Have All the Salmon Gone?

Most notably, the obstruction of fish migration by dams has become increasingly evident in the Pacific Northwest, where damming whole river systems has all but wiped out many historic runs of several salmon species. This has caused the economic base of many communities to be wiped out as well. An acknowledged contributor to the devastating decline of several Pacific Ocean salmon fisheries, dams have helped introduce tight regulations and quotas to commercial fisheries along the whole length of coast all the way to Alaska, with 1994 bringing the first complete salmon closure of both commercial and sportfishing to the West Coast—Alaska yet excepted.

Even with the installation of improved "fish ladders" at dam sites designed to increase the success of fish surmounting these formidable obstacles on their upstream journey to spawn, onsite underwater video cameras now record scant hundreds swimming by a dam where previously salmon filled the rivers and streams each season.

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fish and other organisms. Not only can reservoir water temperatures and oxygen content differ significantly from expected seasonal temperatures in the formerly free-flowing stream or river, but critical minimum flows needed for riparian areas are often not maintained as well. While dams typically reduce or even eliminate the downstream flooding needed by some wetlands and riparian areas to maintain hydrologic conditions, dams can also impede or block fish migration routes. Decreased flow in coastal areas can also increase saltwater intrusion and produce changes in the ecosystem.

Conserving water can improve the adequacy of existing surface water supplies and thus reduce the need for new supply reservoirs. In this way water conservation can help reduce NPS pollution impacts on surface, ground, and coastal waters, as well as impacts on associated habitats that result from constructing new water supply reservoirs.

Overirrigating Agricultural Lands

Irrigation causes the movement of pollutants from land into surface or ground waters. This pollutant movement is affected by:

- The fate of both applied irrigation water and precipitation.
- The physical, chemical, and biological characteristics of the irrigated land.
- The type of irrigation system used.
- The crop type.
- The farm management practices employed.
- The management of the irrigation system.

For example, irrigation waters transported in open, unlined canals can seep into adjacent soils, eventually carrying soluble pollutants into ground or surface waters. Overirrigating results in a portion of applied waters running off the land into surface waters or seeping through the soil and eventually ending up in surface or ground waters. In either case, the excess water can carry these pollutants:

- Sediment and particulate organic solids.
- Particulate-bound nutrients, chemicals, and metals.
- Soluble nutrients, a portion of the applied pesticides, soluble metals (i.e., selenium and iron) and salts, and many other major and minor nutrients.
- Bacteria, viruses, and other microorganisms.

Any pollutants linked to irrigation water—salts, metals, or nutrients—can concentrate in the soil, leachate, seepage, or runoff associated with an irrigation system.

Reducing overall water use in irrigation leaves more water for natural stream flow and increases flow needed by marshes, wetlands, or other environmental uses. If the irrigation source is ground water, reducing overall use maintains higher ground water levels, which could be important for sustaining base flow in nearby streams.

Reduced diversion of surface waters likewise lessens the salt or other pollutant load brought into the irrigation system, thereby diminishing the volume of these pollutants that ultimately must be managed or discharged from the system. One way of managing these pollutants is through the implementation of water conservation and pesticide/nutrient best management practices (BMPs). Decreasing the diversion of water from streams and rivers also lowers the levels of return flows, runoff, and leachate from irrigated lands that might transport pollutants.

Overusing Water to Maintain Urban Landscapes

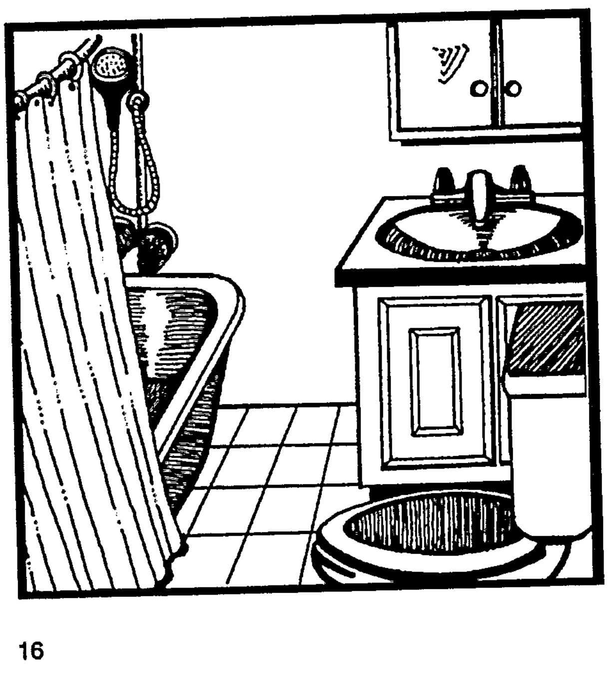
The overuse of water to maintain urban landscapes results in direct and indirect types of NPS pollution. Direct NPS pollution problems associated with water overuse for landscape maintenance include increased nutrient and soil runoff from the landscaped area, as well as other pollutants from urban and developed lands. Indirect NPS pollution problems include increasing overall demand for addi-

tional development and use of water supply reservoirs.

Decreasing the amount of water used for landscape maintenance and implementing pesticide management plans can reduce the entry of these pollutants into surface and ground waters.

Failed or Failing Onsite Disposal Systems

Overusing water in the household can lead to the failure of onsite sewage disposal systems (OSDS), as well as increased addition of pollutants associated with household water uses to surface and ground waters (Table 3). Because many OSDS soil absorption field failures are attributed to hydraulic overload, reducing water use at many locations in the average household—leaking toilets and other fixtures, showers and baths, inefficient appliances such as dishwashers or washing machines—will ease hydraulic loading.



Salinity Intrusion in Coastal Aquifers

Depleting aquifers in coastal areas can lead to salinity intrusion—the movement of chlorides and other minerals into the aquifer. These substances can render ground water undrinkable or require significant expenditures to treat the water before it can be drunk or otherwise used.

Reducing the depletion of aquifers through water efficiency practices or recharging the aquifers with reclaimed (used and treated to appropriate standards) water is an effective way to prevent salinity intrusion.

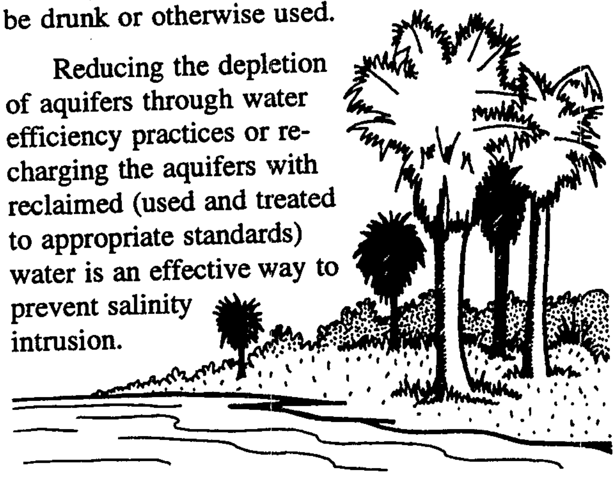


Table 3. Daily domestic water use and pollutant loadings by sources.

Water Use	Volume (gal/capita)	BOD (grams/capita)	Suspended Solids (grams/capita)	Total Nitrogen (grams/capita)	Total Phosphorus (grams/capita)
Garbage Disposal	1.2	10.8	15.9	0.4	0.6
Toilet	16.2	17.2	27.6	8.6	1.2
Basins and Sinks	22.4	22.0	13.6	1.4	2.2
Miscellaneous	6.6	0.0	0.0	0.0	0.0
Total	46.4	50.0	57.1	10.4	4.0

Source: USEPA, 1980.

Salty Water

Saltwater intrusion is a major problem for the Southwest Florida Water Management District, where it has affected numerous wells along the southwestern coast of Florida. Pro-jections by the District forecast continuing saltwater movement inland at a rate of several inches per day. At this rate, hundreds of wells in coastal Hillsborough, Manatee, and Sarasota Counties are at risk (SFWMD,1994).

The results of the Water Resource Assessment Project in the Eastern Tampa Bay area showed that about 150 Mgal/d could be withdrawn without causing further movement of saltwater inland over the next 50 years. Withdrawals in this area average 175 to 200 Mgal/d, yet more than 400 Mgal/d is permitted for withdrawal (SFWMD, 1994).

In Florida, where ground water provides 90 percent of the state's domestic water supply, aquifer recharge has been chosen as the preferred method to decrease the danger of salinity intrusion into ground water supplies (York and Crook, 1990).

Loss/Reduction of Wetlands and Riparian Habitats

Constructing reservoirs reduces streamflow, which modifies erosion and sedimentation patterns, disrupts downstream habitats, and impacts (often negatively) living resources.

Reducing the quantity of water diverted from streams and rivers for water supplies by implementing water use efficiency programs curbs the need to construct new reservoirs for water supply, protecting wetland and riparian habitats as well as their functions in NPS pollution abatement. Many California cities cite the protection of streams, wetlands, and estuaries as a major benefit of and reason for water conservation.

Reduction of Instream Flows

Instream flow is the amount of flow required to sustain stream values, including biota, wildlife, and recreation. In addition to the effects on the quality and quantity of wildlife habitat associated with streams (Table 4), instream flows can also serve many other purposes:

- Stock water by diversion
- Water-based recreation—swimming, rafting, kayaking, boating
- Aesthetics
- Aquifer recharge
- Dilution water for effluent discharges

Table 4. Resources directly or indirectly affected by instream flows with a role in the quality and quantity of wildlife habitat (USDOI, 1992).

Resource	Linkage	Examples
Instream Water	**Direct**	
Water accessible and suitable for drinking	Free water needed on regular (e.g., daily) basis to meet physiological needs	Mule deer, desert bighorn sheep, California and Gambel's quail, other "and land" species
Water of suitable depth and flow	Water used as travel medium (including for dispersal)	River otter, beaver, water shrew, muskrat, many amphibians, some turtles, water snakes
Water of suitable depth, expanse, and clarity	Water area assures exposure or provides concealment (for protection from predators)	Whooping crane, sandhill crane, river otter, beaver, muskrat, water shrew
Water of suitable depth and quality	Water needed as primary residence during some life stage	Frogs, some toads, some salamanders, water snakes, some turtles, mollusks
Variation in flow (Hydroperiod)	Periodic scouring produces vegetation-free sites suitable for feeding or nesting	Shorebirds, terns
Habitat Components	**Indirect**	
Terrestrial insects originating from aquatic larvae	Instream flow determines prey base for terrestrial animals that eat insects	Songbirds, reptiles, and small mammals residing in riparian zone
Mature riparian shrubs and trees	Instream flow affects vegetation that serves as concealment cover for individuals and nests, and that provides shelter from weather	Songbirds breeding or wintering in riparian zone
Terrestrial insects associated with riparian vegetation	Instream flow affects vegetation that produces insects that serve as prey base for animals that eat insects	Songbirds, arboreal lizards, some small mammals
Aquatic animal life	Instream flow determines aquatic animals that serve as food source for semiaquatic species	Birds (dipper, water pipet, some waterfowl, shorebirds); mammals (water shrew, river otters); some salamanders)
Riparian small animal communities	Instream flow directly and indirectly affects structure of community that supports higher food levels	Coyote, red fox, striped skunk, long-tailed weasel, great-horned owl, common black-hawk, aquatic snakes
Fish	Instream flow affects fish populations that support higher food levels	Fish-eating birds and mammals (kingfisher, river otter, osprey)
Aquatic (submerged and emergent) vegetation	Instream flow affects the type and amounts of this vegetation, which is eaten by resident herbivores	Aquatic and semiaquatic herbivores and omnivorous species (larval amphibians, turtles, some waterfowl, rails)
Riparian vegetation	Instream flow affects vegetation that is eaten by resident herbivores	Riparian herbivores, i.e., beaver

Source: USDOI, 1992

from municipal and industrial wastewater sources

- Maintaining water delivery to downstream users
- Channel maintenance and sediment flushing flows.

When drought occurs, natural streamflow might be inadequate to maintain normal instream uses, necessitating additional water to supplement stream flow in these circumstances. Quantitative aids to drought management need to be developed, implemented, refined, and reimplemented, taking into consideration riparian landowner's rights and regional water law. The recommended method of developing quantitative information is by monitoring offstream withdrawals, return flows, and instream flows in addition to precipitation, contributing runoff, evaporation, ground water, reservoir storage, and drought indices.

Swan Flow in Idaho

An instream flow study instituted in the fall of 1989 sought to determine the necessary flows to protect wintering trumpeter swans in Henry's Fork, Idaho. The study was initiated after a severe cold front caused the deaths of 50 to 100 trumpeters despite rapid-response efforts to save them with water to increase flows and open up feeding habitat.

The study concluded that an instream flow of approximately 700 cubic feet per second (ft^3/s), below the confluence of the Buffalo River, would be optimal for swans under normal winter conditions, requiring a release of 500 ft^3/s to achieve that flow. Moreover, those flows would also address fisheries requirements for that reach of Henry's Fork.

The Water Out West

The hydrologic regimes of many western rivers have been drastically altered during the past 100 years. First, water runoff and river baseflows were captured largely to serve mining needs during the early development era. Later, flood control rose in importance together with industrial, municipal, and hydroelectric power needs.

Historically, water use in the West has been based on the premise that "beneficial use" of water requires the user to remove water from the stream to directly serve human needs, with the consequence that instream flow considerations such as fishery resources received little attention. In recent years, however, an emerging environmental awareness and a recognition of endangered, native, and sport fish needs have produced greater interest in maintaining healthy stream and river fish communities. The challenge remains to balance these fishery needs—and the economic benefits of the fishing industry—with those of irrigation, flood control, and municipal and industrial water demands.

Chapter 3

How to Conserve Water and Use It Effectively

Water users can be divided into two basic groups: system users (such as residential users, industries, and farmers) and system operators (such as municipalities, state and local governments, and privately owned suppliers). These users can choose from among many different water use efficiency practices, which fall into two categories:

(1) Engineering practices: practices based on modifications in plumbing, fixtures, or water supply operating procedures.

(2) Behavioral practices: practices based on changing water use habits.

This chapter explores a number of water use efficiency practices. The practices have been evaluated by many researchers, and there is a growing body of literature that presents the results of many studies related to water use efficiency.

This chapter addresses the following questions: What's the problem? What practices might be used to solve it? How effective are they? What do they cost? Where have they been used successfully? Practices for system users—residential, industrial/commercial, and agricultural—are presented first, followed by practices for system operators.

Water Conservation and Use Efficiency Practices

Practices for System Users

Residential Users
- Engineering Practices
  - Plumbing
  - Landscaping
- Behavioral Practices

Industrial/Commercial Users
- Engineering Practices
  - Water Reuse and Recycling
  - Cooling Water Recirculation
  - Rinsing
  - Landscape Irrigation
- Behavioral Practices

Agricultural Users
- Engineering Practices
  - Irrigation
  - Water Reuse and Recycling
- Behavioral Practices
  - Irrigation Scheduling

Practices for System Operators

Engineering Practices
- Metering
- Leak Detection
- Water Main Rehabilitation
- Water Reuse
- Well Capping

Planning and Management Practices
- Pricing
- Retrofit Programs
- Residential Water Audit Programs
- Public Education
- Index of Water Efficiency
- Planning for Resource Protection
- Drought Management Planning

Practices for Residential Users

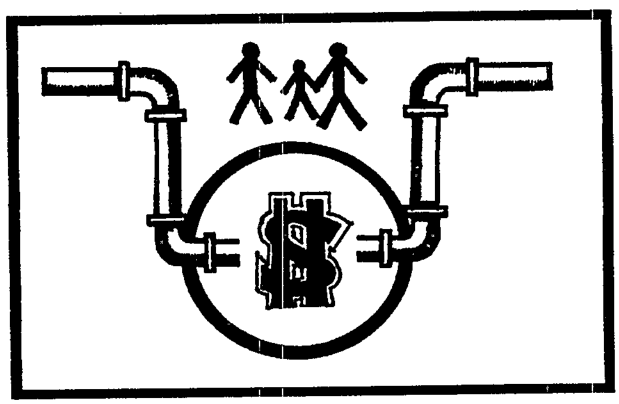
The following sections present examples of conservation and water use efficiency practices that can benefit residential users. Both engineering and behavioral practices are described.

Engineering Practices

Plumbing

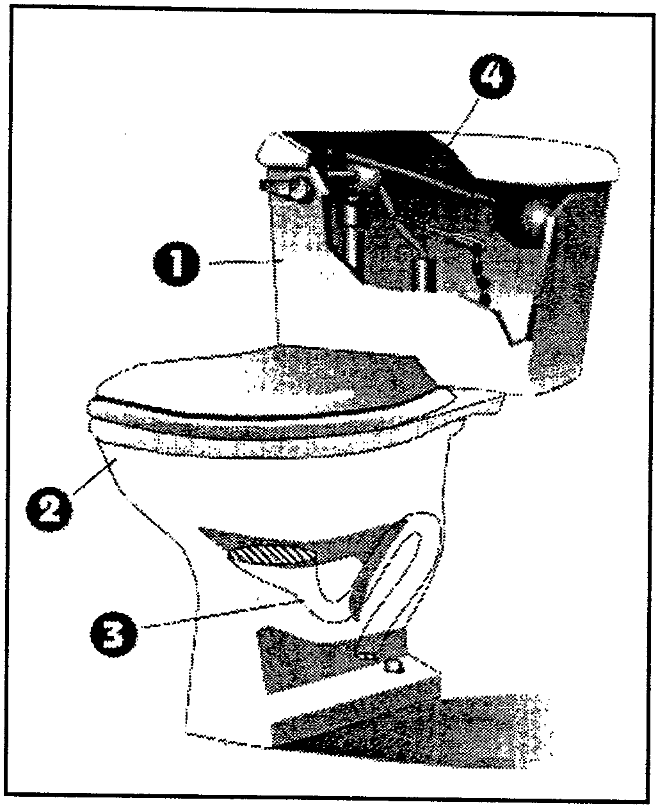
An engineering practice for individual residential water users is the installation of indoor plumbing fixtures that save water or the replacement of existing plumbing equipment with equipment that uses less water. Low-flow plumbing fixtures and retrofit programs are permanent, one-time conservation measures that can be implemented automatically with little or no additional cost over their life times (Jensen, 1991). In some cases, they can even save the resident money over the long term.

The City of Corpus Christi, for example, has estimated that an average three-member household can reduce its water use by 54,000 gallons annually and can lower water bills by about $60 per year if water-efficient plumbing fixtures are used (Jensen, 1991). Further support for this conclusion is provided below.



By using water-efficient plumbing, a family of three can reduce its water use and save $60 per year.

Low-Flush Toilets. Residential demands account for about three-fourths of the total urban water demand. Indoor use accounts for roughly 60 percent of all residential use, and of this, toilets (at 3.5 gallons per flush) use nearly 40 percent. Toilets, showers, and faucets combined represent two-thirds of all indoor water use. More than 4.8 billion gallons of water is flushed down toilets each day in the United States. The average American uses about 9,000 gallons of water to flush 230 gallons of waste down the toilet per year (Jensen, 1991). In new



The gravity design is the most widely available low-flush toilet. When flushing, the stored water from the tank (1) flows into the bowl (2), where the water pushes waste into the trapway (3). The 1.6-gal/flush design of the gravity toilet has a different flush mechanism (4), as well as steep bowl sides and a narrow trapway to allow the siphoned water to gain velocity for more effective removal of waste (City of Austin, n.d.).

construction and building rehabilitation or remodeling there is a great potential to reduce water consumption by installing low-flush toilets.

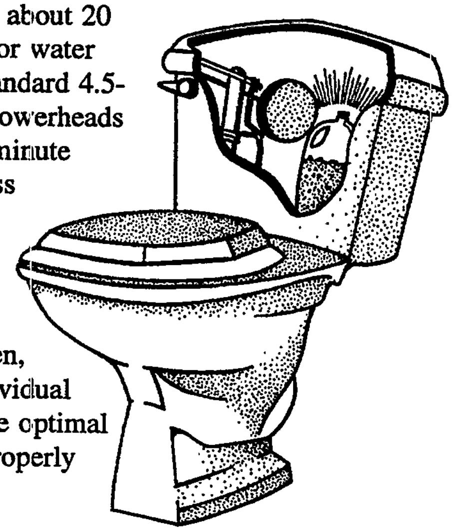
Conventional toilets use 3.5 to 5 gallons or more of water per flush, but low-flush toilets (see figure above) use only 1.6 gallons of water or less. Since low-flush toilets use less water, they also re-duce the volume of wastewater produced (Pearson, 1993).

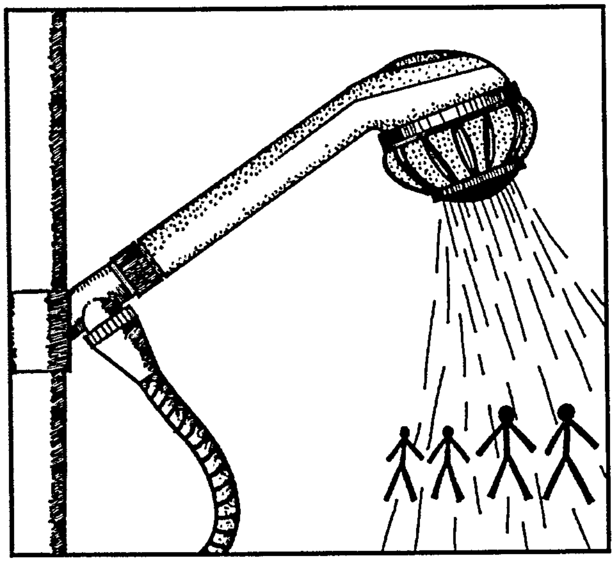
Effective January 1, 1994, the Energy Policy Act of 1992 (Public Law 102-486) requires that all new toilets produced for home use must operate on 1.6 gallons per flush or less (Shepard, 1993). Toilets that operate on 3.5 gallons per flush will continue to be manufactured, but their use will be allowed for only certain commercial applications through January 1, 1997 (NAPHCC, 1992).

Even in existing residences, replacement of conventional toilets with low-flush toilets is a practical and economical alternative. The effectiveness of low-flush toilets has been demonstrated in a study in the City of San Pablo, California. In a 30-year-old apartment building, conventional toilets that used about 4.5 gallons per flush were replaced with low-flush toilets that use approximately 1.6 gallons per flush. The change resulted in a decrease in water consumption from approximately 225 gallons per day per average household of 3½ persons to 148 gallons per day per household—a savings of 34 percent! Although the total cost for replacement of the conventional toilets with low-flush toilets was about $250 per unit (including installation), the water conservation fixtures saved an average of $46 per year from each unit's water bill. Therefore, the cost for the replacement of the conventional toilet with a low-flush toilet could be recovered in 5.4 years.

Toilet Displacement Devices. Plastic containers (such as plastic milk jugs) can be filled with water or pebbles and placed in a toilet tank to reduce the amount of water used per flush. By placing one to three such containers in the tank (making sure that they do not interfere with the flushing mechanisms or the flow of water), more than 1 gallon of water can be saved per flush. A toilet dam, which holds back a reservoir of water when the toilet is flushed, can also be used instead of a plastic container to save water. Toilet dams result in a savings of 1 to 2 gallons of water per flush (USEPA, 1991b).

Low-Flow Showerheads. Showers account for about 20 percent of total indoor water use. By replacing standard 4.5-gallon-per-minute showerheads with 2.5-gallon-per-minute heads, which cost less than $5 each, a family of four can save approximately 20,000 gallons of water per year (Jensen, 1991). Although individual preferences determine optimal shower flow rates, properly designed low-flow





Replacing standard showerheads with low-flow showerheads can save a family of four about 20,000 gallons of water per year.

showerheads are available to provide the quality of service found in higher-volume models.

Whitcomb (1990) developed a model to estimate water use savings resulting from the installation of low-flow showerheads in residential housing. Detailed data from 308 single-family residences involved in a pilot program in Seattle, Washington, were analyzed. The estimated indoor water use per person dropped 6.4 percent after low-flow showerheads were installed (Whitcomb, 1990).

Faucet Aerators. Faucet aerators, which break the flowing water into fine droplets and entrain air while maintaining wetting effectiveness, are inexpensive devices that can be installed in sinks to reduce water use. Aerators can be easily installed and can reduce the water use at a faucet by as much as 60 percent while still maintaining a strong flow. More efficient kitchen and bathroom faucets that use only 2 gallons of water per minute—unlike standard faucets, which use 3 to 5 gallons per minute—are also available (Jensen, 1991).

Pressure Reduction. Because flow rate is related to pressure, the maximum water flow from a fixture operating on a fixed setting can be reduced if the water pressure is reduced. For example, a reduction in pressure from 100 pounds per square inch to 50 psi at an outlet can result in a water flow reduction of about one-third (Brown and Caldwell, 1984).

Homeowners can reduce the water pressure in a home by installing pressure-reducing valves. The use of such valves might be one way to decrease water consumption in homes that are served by municipal water systems. For homes served by wells, reducing the system pressure can save both water and energy. Many water use fixtures in a home, however, such as washing machines and toilets, operate on a controlled amount of water, so a reduction in water pressure would have little effect on water use at those locations.

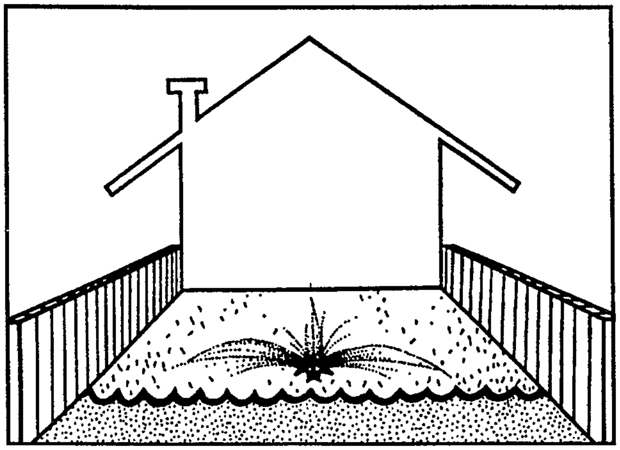
A reduction in water pressure can save water in other ways: it can reduce the likelihood of leaking water pipes, leaking water heaters, and dripping faucets. It can also help reduce dishwasher and washing machine noise and breakdowns in a plumbing system.

A study in Denver, Colorado, illustrates the effect of water pressure on water savings. Water use in homes was compared among different water pressure zones throughout the city. Elevation of a home with respect to the elevation of a pumping station and the proximity of the home to the pumping station determine the pressure of water delivered to each home. Homes with high water pressure were compared to homes with low water pressure. An annual water savings of about 6 percent was shown for homes that received water service at lower pressures when compared to homes that received water services at higher pressures.

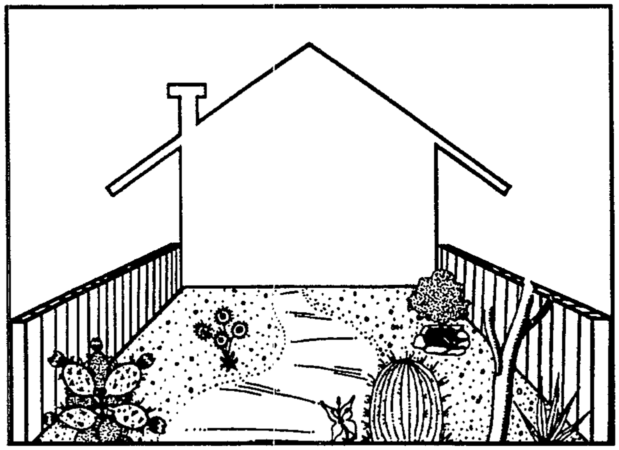
Gray Water Use. Domestic wastewater composed of wash water from kitchen sinks and tubs, clothes washers, and laundry tubs is called gray water (USEPA, 1989). Gray water can be used by homeowners for home gardening, lawn maintenance, landscaping, and other innovative uses. The City of St. Petersburg, Florida, has implemented an urban dual distribution system for reclaimed water for nonpotable uses. This system provides reclaimed water for more than 7,000 residential homes and businesses (USEPA, 1992).

Landscaping

Lawn and landscape maintenance often requires large amounts of water, particularly in areas with low rainfall. Outdoor residential water use varies greatly depending on geographic location and season. On an annual average basis, outdoor water use



Nationally, lawn care typically accounts for 32 percent of total residential outdoor water use.



Xeriscape landscaping can significantly reduce water usage.

in the arid West and Southwest is much greater than that in the East or Midwest. Nationally, lawn care accounts for about 32 percent of the total residential outdoor use. Other outdoor uses include washing automobiles, maintaining swimming pools, and cleaning sidewalks and driveways.

Landscape Irrigation. One method of water conservation in landscaping uses plants that need little water, thereby saving not only water but labor and fertilizer as well (Grisham and Fleming, 1989). A similar method is grouping plants with similar water needs. Scheduling lawn irrigation for specific early morning or evening hours can reduce water wasted due to evaporation during daylight hours. Another water use efficiency practice that can be applied to residential landscape irrigation is the use of cycle irrigation methods to improve penetration and reduce runoff. Cycle irrigation provides the right amount of water at the right time and place, for optimal growth. Other practices include the use of low-precipitation-rate sprinklers that have better distribution uniformity, bubbler/soaker systems, or drip irrigation systems (RMI, 1991).

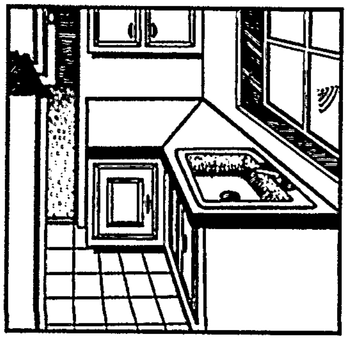
Xeriscape Landscapes. Careful design of landscapes could significantly reduce water usage nationwide. Xeriscape landscaping is an innovative, comprehensive approach to landscaping for water conservation and pollution prevention. Traditional landscapes might incorporate one or two principles of water conservation, but xeriscape landscaping uses all of the following: planning and design, soil analysis, selection of suitable plants, practical turf areas, efficient irrigation, use of mulches, and appropriate maintenance (Welsh et al., 1993).

Benefits of xeriscape landscaping include reduced water use, decreased energy use (less pumping and treatment required), reduced heating and cooling costs because of carefully placed trees, decreased storm water and irrigation runoff, fewer yard wastes, increased habitat for plants and animals, and lower labor and maintenance costs (USEPA, 1993).

More than 40 states have initiated xeriscape projects. Some communities use contests and demonstration gardens to promote public awareness. El Paso Water Utilities and the Council of El Paso Garden Clubs sponsor an annual "Accent Sun Country" contest. The contest spotlights homes that have water-conserving landscapes consisting of plants and grasses that require only a minimum of supplemental water and yet beautify the homes. The winning entries are publicized, and cash prizes are awarded. People are invited to tour the grounds to get ideas on how they, too, can save water, time, and money while maintaining an attractive landscape (RMI, 1991). The offices of the Southwest Florida Water Management District in Tampa and Brooksville offer free xeriscape tours every month. The tours begin with a slide show on the principles of xeriscape and continue with a walking tour of water-saving landscaping (Xeriscape tours, 1993).

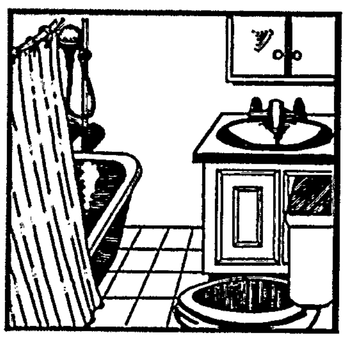
Behavioral Practices

Behavioral practices involve changing water use habits so that water is used more efficiently, thus reducing the overall water consumption in a home. These practices require a change in behavior, not modifications in the existing plumbing or fixtures in a home. Behavioral practices for residential water users can be applied both indoors in the kitchen, bathroom, and laundry room and outdoors.



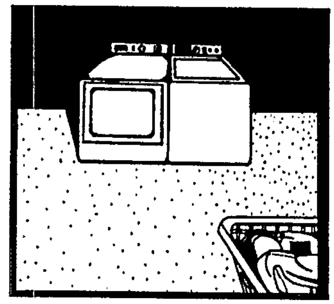
In the kitchen, for example, 10 to 20 gallons of water a day can be saved by running the dishwasher only when it is full. If dishes are washed by hand, water can be saved by filling the sink or a dishpan with water rather than running the water continuously. An open conventional faucet lets about 5 gallons of water flow every 2 minutes (Florida Commission, 1990).

Water can be saved in the bathroom by turning off the faucet while brushing teeth or shaving. Water can be saved by taking short showers rather than long showers or baths and turning the water off while soaping. This water savings can be increased even further by installing low-flow showerheads, as discussed earlier. Toilets should be used only to carry away sanitary waste.



Households with lead-based solder in pipes that flush the first several gallons of water should collect this water for alternative nonpotable uses (e.g., plant watering).

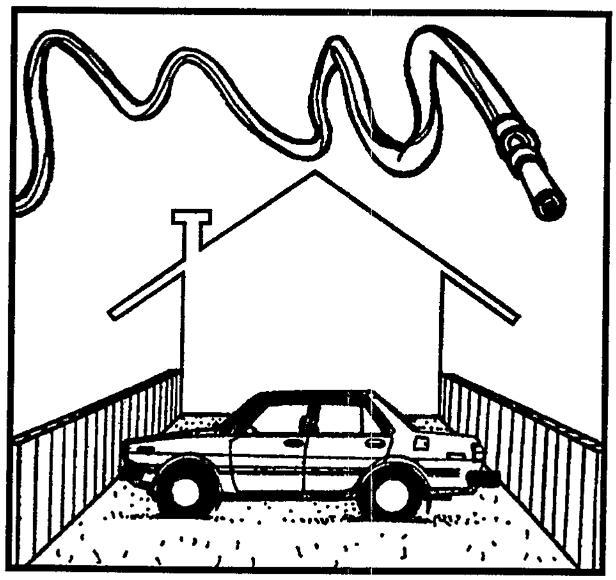
Water can be saved in the laundry room by adjusting water levels in the washing machine to match the size of the load. If the washing machine does not have a variable load control, water can be saved by running the machine only when it is full. If washing is done by hand, the water should not be left running. A laundry tub should be filled with water, and the wash and rinse water should be reused as much as possible.



Outdoor water use can be reduced by watering the lawn early in the morning or late in the evening and on cooler days, when possible, to reduce evaporation. Allowing the grass to grow slightly taller will reduce water loss by providing more ground shade for the roots and by promoting water retention in the soil. Growing plants that are suited to the area ("indigenous" plants) can save more than 50 percent of the water normally used to care for outdoor plants.

As much as 150 gallons of water can be saved when washing a car by turning the hose off between rinses. The car should be washed on the lawn if possible to reduce runoff.

Additional savings of water can result from sweeping sidewalks and driveways instead of hosing them down. Washing a sidewalk or driveway with a hose uses about 50 gallons of water every 5 minutes (Florida Commission, 1990). If a home has an outdoor pool, water can be saved by covering the pool when it is not in use.



Water can be saved by turning off the hose between rinses, and runoff can be reduced by washing the car on the lawn.

Practices for Industrial/ Commercial Users

Industrial/commercial users can apply a number of conservation and water use efficiency practices. Some of these practices can also be applied by users in the other water use categories.

Engineering Practices

Water Reuse and Recycling

Water *reuse* is the use of wastewater or reclaimed water from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be used for a beneficial purpose and in accordance with applicable rules (such as local ordinances governing water reuse). Some potential applications for the reuse of wastewater or reclaimed water include other industrial uses, landscape irrigation, agricultural irrigation, aesthetic uses such as fountains, and fire protection (USEPA, 1992). Factors that should be considered in an industrial water reuse program include (Brown and Caldwell, 1990):

- Identification of water reuse opportunities.
- Determination of the minimum water quality needed for the given use.
- Identification of wastewater sources that satisfy the water quality requirements.
- Determination of how the water can be transported to the new use.

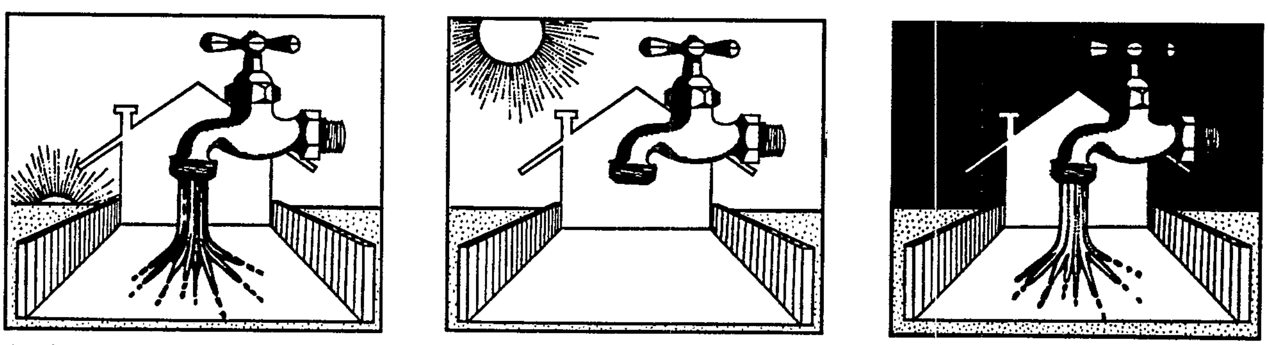
Water Reuse

Water reuse has been applied at the General Products Division facility of IBM, located in San Jose, California, where data storage systems are developed and manufactured for use with mainframe computers. Industrial wastewater effluent at the facility is treated and then reused for cooling tower makeup in the facility's 17,000-ton cooling tower system (Brown and Caldwell, 1990).

The treated industrial wastewater effluent is of higher quality than the well water that was previously used for cooling tower makeup, so water discharges from the tower have also been reduced. The total reduction in fresh-water use requirements at the IBM facility is approximately 100 million gallons per year, resulting in a savings of approximately $153,000 per year (1989 dollars)(Brown and Caldwell, 1990).

The reuse of wastewater or reclaimed water is beneficial because it reduces the demands on available surface and ground waters (Strauss, 1991). Perhaps the greatest benefit of establishing water reuse programs is their contribution in delaying or eliminating the need to expand potable water supply and treatment facilities (USEPA, 1992).

Water *recycling* is the reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be used again. Factors that should be considered in a water recycling program include (Brown and Caldwell, 1990):



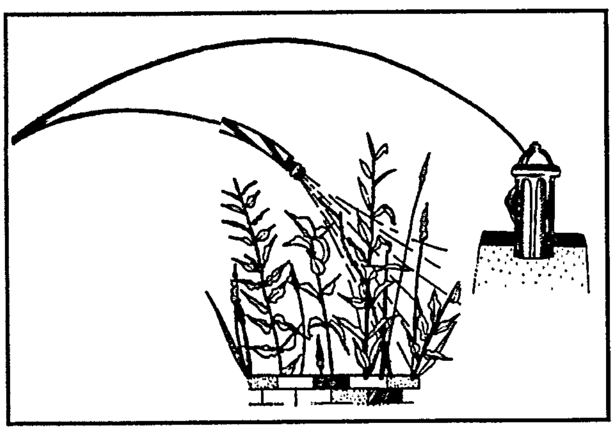
Outdoor water use can be reduced by watering the lawn early in the morning or late in the evening.

Water Recycling

Water recycling is used at the Container Corporation of America's Mill in Santa Clara, California. The mill manufactures paperboard from the recycled fibers of newspapers, corrugated clippings, and ledger paper. The mill has reduced water use through the clarification and recycling of fresh water in its rinsing processes. The mill also installed a closed-loop cooling tower, which has resulted in an additional reduction in water use (Brown and Caldwell, 1990).

The water conservation and use efficiency practices implemented at the Container Corporation of America mill have resulted in an estimated savings of approximately 720,000 gallons per day when compared to its 1980 water use rates. These water reductions amount to approximately 250 million gallons per year and save the company approximately $348,200 per year (1989 dollars)(Brown and Caldwell, 1990).

- Identification of water reuse opportunities.
- Evaluation of the minimum water quality needed for a particular use.
- Evaluation of water quality degradation resulting from the use.
- Determination of the treatment steps, if any, that might be required to prepare the water for recycling.



Industrial wastewater can sometimes be reused for irrigation, fire protection, and other purposes.

Cooling Water Recirculation

The use of water for cooling in industrial applications represents one of the largest water uses in the United States. Water is typically used to cool heat-generating equipment or to condense gases in a thermodynamic cycle. The most water-intensive cooling method used in industrial applications is once-through cooling, in which water contacts and lowers the temperature of a heat source and then is discharged.

Recycling water with a recirculating cooling system can greatly reduce water use by using the same water to perform several cooling operations. The water savings are sufficiently substantial to result in overall cost savings to the industry (see box). Three cooling water conservation approaches that can be used to reduce water use are evaporative cooling, ozonation, and air heat exchange (Brown and Caldwell, 1990).

In industrial/commerical *evaporative cooling* systems, water loses heat when a portion of it is

Recirculating Cooling Water

International Microelectronic Products, located in North San Jose, California, manufactures integrated circuits. Water is used to cool equipment in the manufacturing process. Equipment cooling at the facility was previously accomplished with one-time use of fresh water. The cooling system equipment was converted to a closed-loop, heat exchanger chilling system to reduce water consumption.

The conversion from a one-time freshwater cooling system to a closed-loop cooling system with circulating chilled water has resulted in an estimated water savings of from 5,000 to 7,000 gallons per day at the facility.

Combined water conservation practices at International Microelectronic Products, including reduced use of deionized water, reuse of reverse osmosis reject water, conversion to a closed-loop cooling system, and implementation of a water use monitoring program, have resulted in an estimated savings of $181,000 per year (1989 dollars) (Brown and Caldwell, 1990).

evaporated. Water is lost from evaporative cooling towers as the result of evaporation, drift, and blowdown. (Blowdown is a process in which some of the poor-quality recirculating water is discharged from the tower in order to reduce the total dissolved solids.) Water savings associated with the use of evaporative cooling towers can be increased by reducing blowdown or water discharges from cooling towers.

The use of ozone to treat cooling water (*ozonation*) can result in a five-fold reduction in blowdown when compared to traditional chemical treatments and should be considered as an option for increasing water savings in a cooling tower (Brown and Caldwell, 1990).

Air heat exchange works on the same principle as a car's radiator. In an air heat exchanger, a fan blows air past finned tubes carrying the recirculating cooling water. Air heat exchangers involve no water loss, but they can be relatively expensive when compared with cooling towers (Brown and Caldwell, 1990).

The Pacific Power and Light Company's Wyodak Generating Station in Wyoming decided to use dry cooling to eliminate water losses from cooling-water blowdown, evaporation, and drift. The station was equipped with the first air-cooled condenser in the western hemisphere. Steam from the turbine is distributed through overhead pipes to finned carbon steel tubes. These are grouped in rectangular bundles and installed in A-frame modules above 69 circulating fans. The fans force some 45 million cubic feet per minute (ft^3/min) of air through 8 million square feet of finned-tube surface, condensing the steam (Strauss, 1991).

The payback comes from the water savings. Compared to about 4,000 gallons per minute (gal/min) of makeup (replacement water) for equivalent evaporative cooling, the technique reduces the station's water requirement to about 300 gal/min (Strauss, 1991).

Rinsing

Another common use of water by industry is the application of deionized water for removing contaminants from products and equipment. Deionized water contains no ions (such as salts), which tend to corrode or deposit onto metals. Historically, industries have used deionized water excessively to provide maximum assurance against contaminated products. The use of deionized water can be reduced without affecting production quality by eliminating some plenum flushes (a rinsing procedure that discharges deionized water from the rim of a flowing bath to remove contaminants from the sides and bottom of the bath), converting from a continuous-flow to an intermittent-flow system, and improving control of the use of deionized water (Brown and Caldwell, 1990).

Deionized water can be recycled after its first use, but the treatment for recycling can include many of the processes required to produce deionized water from municipal water. The reuse of once-used deionized water for a different application should also be considered by industry, where applicable, because deionized water is often more

Rinsing Modifications

Advanced Micro Devices is a semiconductor manufacturer in Sunnyvale and Santa Clara, California. Large volumes of ultra-pure deionized water are required to rinse contaminants from wafers. The modification of rinse sinks to more efficiently use water and a reduction in rinse water rejection rates have resulted in reduced deionized water use at the facility (Brown and Caldwell, 1990).

The modification of wafer fabrication rinse sinks at Advanced Micro Devices has reduced deionized water use from approximately 280 to 300 gal/min to 180 to 200 gal/min. The water use reduction at the facility represents a savings of from 80 to 120 gal/min, which is equivalent to 115,000 to 173,000 gal/d. Reduction of the reverse osmosis rinse water rejection rate resulted in a water savings of about 20 gal/min, which is equivalent to about 29,000 gal/d (Brown and Caldwell, 1990).

Modification of the sinks in the wafer fabrication facility at Advanced Micro Devices, when combined with capital costs, has resulted in a savings of approximately $81,300 per year (1989 dollars) (Brown and Caldwell, 1990).

pure after its initial use than municipal water (Brown and Caldwell, 1990).

Landscape Irrigation

Another way that industrial/commercial facilities can reduce water use is through the implementation of efficient landscape irrigation practices. There are several general ways that water can be more efficiently used for landscape irrigation, including the design of landscapes for low maintenance and low water requirements (refer to the previous section on xeriscape landscaping), the use of water-efficient irrigation equipment such as drip systems or deep root systems, the proper maintenance of irrigation equipment to ensure that it is working properly, the distribution of irrigation equipment to make sure that water is dispensed evenly over areas where it is needed, and the scheduling of irrigation to ensure maximum water use (Brown and Caldwell, 1990). For additional information on efficient water use for irrigation, refer to the practices for residential users and agricultural users in this chapter.

Behavioral Practices

Behavioral practices involve modifying water use habits to achieve more efficient use of water, thus reducing overall water consumption by an industrial/commercial facility. Changes in behavior can save water without modifying the existing equipment at a facility.

Monitoring the amount of water used by an industrial/commercial facility can provide baseline information on quantities of overall company water use, the seasonal and hourly patterns of water use, and the quantities and quality of water use in individual processes. Baseline information on water use can be used to set company goals and to develop specific water use efficiency measures. Monitoring can make employees more aware of water use rates and makes it easier to measure the results of conservation efforts. The use of meters on individual pieces of water-using equipment can provide direct information on the efficiency of water use. Records of meter readings can be used to identify changes in water use rates and possible problems in a system (Brown and Caldwell, 1990).

Behavioral Changes Save Food Processor Water and Money

Gangi Brothers Packing Company is a tomato processing and canning plant in Santa Clara, California. Gangi Brothers has implemented several successful water conservation practices at its cannery, including the monitoring of operations to control water use and to identify areas where water could be saved. Monitoring of water use at the facility has been used to establish reasonable water use practices, to notify employees of the proper practices, and to monitor and enforce proper water use practices (Brown and Caldwell, 1990).

Over a 5-year period the combined conservation practices at the packing company have resulted in a significant reduction in water use. In 1983 Gangi Brothers used approximately 148 billion gallons of water during the canning season. By 1989 water use at the facility had dropped to 56.8 billion gallons, resulting in a savings of 91.4 billion gallons per season (Brown and Caldwell, 1990).

Combined estimated capital and operating costs for water conservation at Gangi Brothers are approximately $89,500 per year. The estimated savings from lower sewer and water costs is $130,000 per year, so the net savings resulting from the implementation of water conservation practices at the cannery is approximately $40,500 per year (1990 dollars) (Brown and Caldwell, 1990).

Many of the practices described in the section for residential users can also be applied by commercial users. These include low-flow fixtures, water-efficient landscaping, and water reuse and recycling (e.g., using recycled wash water for pre-rinse).

Practices for Agricultural Users

Engineering Practices

Irrigation

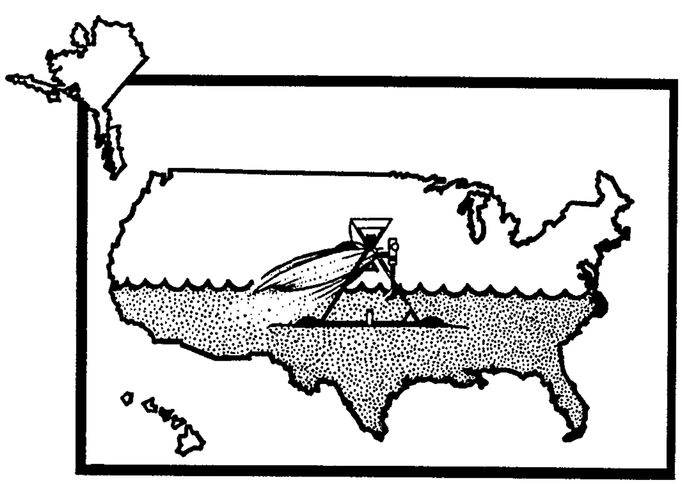
Water-saving irrigation practices fall into three categories: field practices, management strategies, and system modifications. *Field practices* are techniques that keep water in the field, distribute water more efficiently across the field, or encourage the retention of soil moisture. Examples of these practices include the chiseling of extremely compacted soils, furrow diking to prevent runoff, and leveling of the land to distribute water more evenly. Typically, field practices are not very costly.

Management strategies involve monitoring soil and water conditions and collecting information on water use and efficiency. The information helps in making decisions about scheduling applications or improving the efficiency of the irrigation system. The methods include measuring rainfall, determining soil moisture, checking pumping plant efficiency, and scheduling irrigation.

System modifications require making changes to an existing irrigation system or replacing an existing system with a new one. Because system modifications require the purchase of equipment, they are usually more expensive than field practices and management strategies. Typical system modifications include adding drop tubes to a center pivot system, retrofitting a well with a smaller pump, installing surge irrigation, or constructing a tailwater recovery system (Kromm and White, 1990).

Water Reuse and Recycling

Agricultural irrigation represents approximately 40 percent of the total water demand nationwide. Given that high demand, significant water conservation benefits could result from irrigating with reused or recycled water.



Agricultural irrigation represents about 40 percent of the total freshwater withdrawals (Solley et al., 1993).

Agricultural Water Reuse

An example of an agricultural application of water reuse is at a farm outside Tallahassee, Florida. The Tallahassee, Florida, agricultural reuse system is a cooperative operation in which the city owns and maintains the irrigation system on a farm leased to a commercial enterprise. Reclaimed water from the city's secondary wastewater treatment plant has been used for spray irrigation since 1966. After receiving secondary treatment, reclaimed water is pumped approximately 8.5 miles (13.7 km) from the Thomas P. Smith wastewater renovation plant in Tallahassee to the spray field and is then distributed by 13 center-pivot irrigation units. Permitted application rates at the site are 3.16 inches per week for a total capacity of 21.5 Mgal/d. The major crops produced at the spray field include corn, soybeans, coastal Bermuda grass, and rye (USEPA, 1992).

Studies of the system in 1971 showed that it was successful in producing crops for agricultural use and that the soil was effective at removing suspended solids, biochemical oxygen demand, bacteria, nitrogen, and phosphorus from the reclaimed water. The Southeast Spray Field has been expanded twice since 1980 and now has a total area of approximately 1,750 acres (USEPA, 1992).

Water reuse is the use of wastewater or reclaimed water from one application for another application. Reused water must be used for a beneficial purpose and in accordance with applicable rules (USEPA, 1991a). Water recycling is the reuse of water for the same application for which it was originally intended.

Factors that should be considered in an agricultural water reuse program include:

- The identification of water reuse opportunities.
- Determination of the minimum water quality needed for the given use.
- Identification of wastewater sources that satisfy the water quality requirements.

- Determination of how the water can be transported to the new use (Brown and Caldwell, 1990).

Water reuse for irrigation is already in widespread use in rural areas and is also applicable in areas where agricultural sites are near urban areas and can easily be integrated with urban reuse applications (USEPA, 1992).

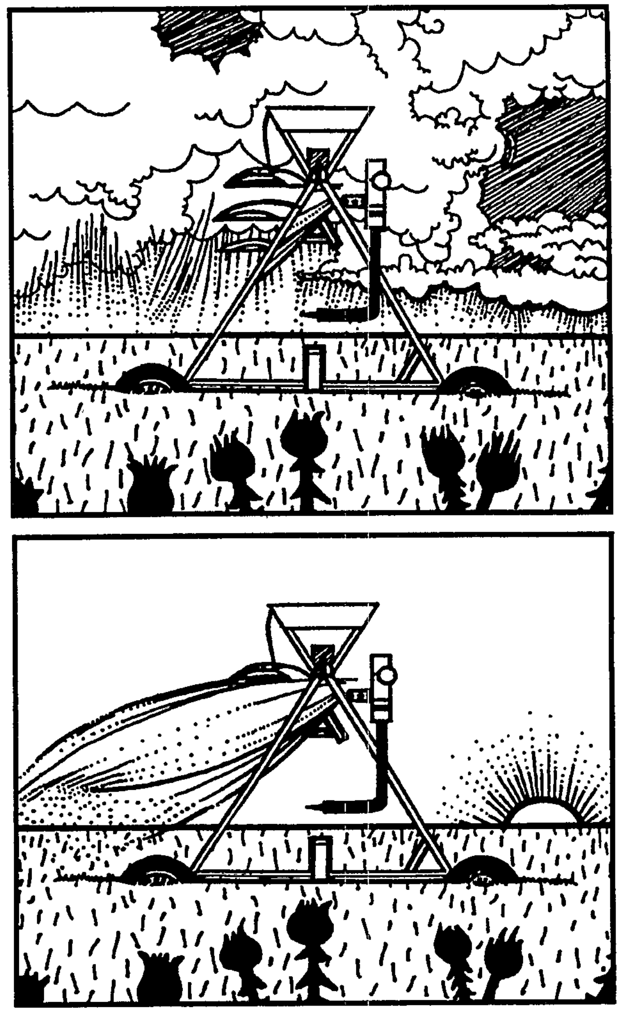
Behavioral Practices

Behavioral practices involve changing water use habits to achieve more efficient use of water. Behavioral practices for agricultural water users can be applied to irrigation application rates and timing. Changes in water use behavior can be implemented without modifying existing equipment.

For example, better irrigation scheduling can result in a reduction in the amount of water that is required to irrigate a crop effectively. The careful choice of irrigation application rates and timing can help farmers to maintain yields with less water. In making scheduling decisions, irrigators should consider:

- The uncertainty of rainfall and crop water demand.
- The limited water storage capacity of many irrigated soils.
- The limited pumping capacity of irrigation systems.
- Rising pumping costs as a result of higher energy prices.

Local NRCS-Conservation Districts and Cooperative Extension Service offices can play an important role in promoting better irrigation scheduling. Accurate information on crop water use requires information on solar radiation and other weather variables that can be collected by local weather stations. An additional method that can be used to improve irrigation scheduling and might result in high returns is the use of equipment such as resistance blocks, tensiometers, and neutron probes to monitor soil moisture conditions to help in determining when water should be applied (Bosch and Ross, 1990).



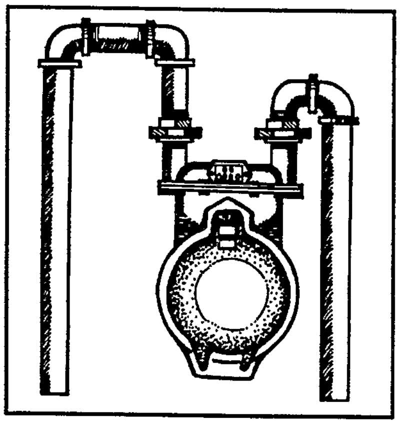
Better irrigation scheduling can result in water savings.

Practices for System Operators

Engineering Practices

Metering

Metering. The measurement of water use with a meter provides essential data for charging fees based on actual customer use. Billing customers based on their actual water use has been found to contribute directly to water conservation. Meters also aid in detecting leaks throughout a water system. In 1977, for example, Boston, Massachusetts, could not account for the use of 50 percent of the water in its municipal water



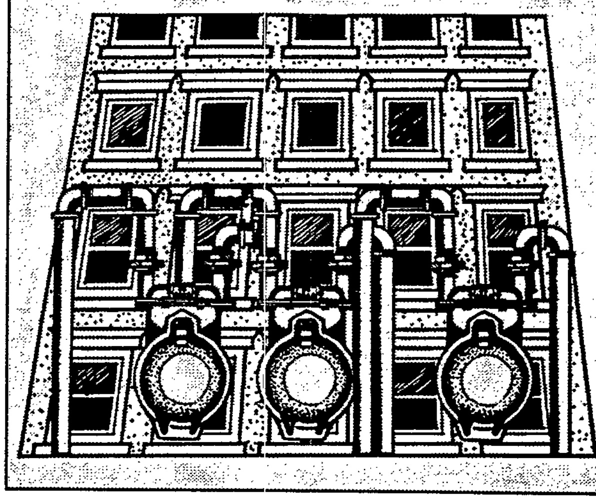
Metering provides essential data on water use and can help to detect leaks.

system. After installing meters, the city identified leaks and undertook a vigorous leak detection program (Grisham and Fleming, 1989). Unaccounted-for water dropped to 36 percent after metering and leak detection programs were started.

Submetering. Submetering is used in units such as apartments, condominiums, and trailer homes to indicate water use by those individual units; the entire complex of units is metered by the main supplier. Submetering of water use in apartment or business complexes makes it possible to bill tenants for the water that they actually use rather than for a percentage of the total water use for the complex. Submetering makes water users more aware of how much water they use and its cost, and tenants who conserve water can benefit from lower water use costs. Submetering is reported to reduce water usage by 20 to 40 percent (Rathnau, 1991).

Submetering

In a New York City apartment building not using submeters, average daily water use ranged from 375 to 425 gallons per apartment per day. An apartment building in Washington, DC, that did use submetering was found to use from 90 to 160 gallons per apartment per day (Rathnau, 1991).



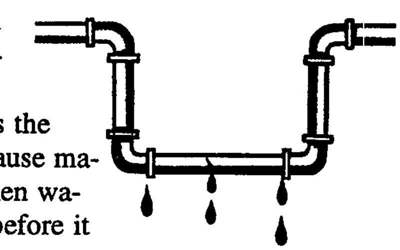
Metering in Denver

According to the Denver Water Department, meter installation costs are about $250 (1989 dollars) for interior meters and about $500 for exterior meters (Grisham and Fleming, 1989). The Denver Water Department is implementing a metering program, which is part of a package of practices being used as an alternative to constructing a new reservoir. The water department will install more than 87,000 meters. Predicted total costs are around $20 million. The program is expected to reduce water use by over 3.6 billion gallons per year by 1999. The cost of supplying this amount of water through reservoir construction (estimated at $0.0023 per gallon) would be more than $8.4 million per year (USEPA, 1990d). Thus, the benefits from reduced water supply needs created by this project will cover the costs in less than 3 years once the program begins to achieve its full effect.

Leak Detection

One way to detect leaks is to use listening equipment to survey the distribution system, identify leak sounds, and pinpoint the exact locations of hidden underground leaks. As mentioned in the previous section, metering can also be used to help detect leaks in a system.

An effective way to conserve water is to detect and repair leaks in municipal water systems. Repairing leaks controls the loss of water that water agencies have paid to obtain, treat, and pressurize. The early detection of leaks also reduces the chances that leaks will cause major property damage. When water leaks from a system before it reaches the consumer, water



Leak Detection Coast to Coast

The California Department of Water Resources (DWR) estimates that about 81 billion gallons of water leaks from municipal systems in California each year. In DWR's experience with local water agencies, leak detection projects have been found to be cost-effective. Leaking water can be controlled at a cost averaging less than $153 (1992 dollars) per million gallons—a cost usually less than what a water agency pays for the water (California Department of Water Resources, 1992).

In 1988, as the result of conducting leak detection surveys, the Boston Water and Sewer Commission discovered and repaired 888 leaks that were wasting an estimated 11.55 Mgal/d. By 1989, 819 miles of Boston's 1182 miles of water distribution system had been surveyed. These surveys resulted in the detection of 444 leaks, 427 of which had been repaired by January 1990, saving an additional 7.16 Mgal/d (RMI, 1991).

New York City has an ongoing leak detection program. The goal is to survey all 33.6 million feet of water mains with computerized electronic leak detection equipment. As of September 1989, survey crews had examined over 31 million feet of water mains and had eliminated the loss of an estimated 89 Mgal/d in leaks. The New York City Department of Environmental Protection estimates that leakage makes up nearly 10 percent of New York City's total water demand. Another benefit from leak detection is that the water not leaked will also not infiltrate into the sewer lines and increase wastewater flows (RMI, 1991).

agencies lose revenue and incur unnecessary costs. Such costs should provide an incentive for system operators to implement a leak detection program.

Programs for finding and repairing leaks in water mains and laterals (conduits) might be cost-effective in spite of their high initial costs. Leak detection programs have been especially important in cities that have large, old, deteriorating systems (RMI, 1991).

Water Main Rehabilitation

A water utility can improve the management and rehabilitation of a water distribution network by using a distribution system database. Using the database can help to lower maintenance costs and can result in more efficient use of the water resource. The database can help the utility manager to set priorities and efficiently allocate rehabilitation funds (Habibian, 1992). A comprehensive database should include information on the following:

- The characteristics of the system's components, such as size, age, and material
- The condition of mains, such as corrosion
- Soil conditions or type
- Failure and leak records
- Water quality
- High/low pressure problems
- Operating records, such as pump and valve operations
- Customer complaints
- Meter data
- Operating and rehabilitation costs.

Water Reuse

Another practice that should be considered by water system operators who operate publicly owned treatment works is the reuse of treated wastewater. As discussed earlier, water reuse is the use of wastewater or reclaimed water from one application for another application. Some potential applications for water reuse include landscape irrigation, agricultural irrigation, aesthetic uses such as fountains, industrial uses, and fire protection (USEPA, 1991a). These factors should be considered in a water reuse program:

- The identification of water reuse opportunities.
- The determination of the minimum water quality needed for the given use.

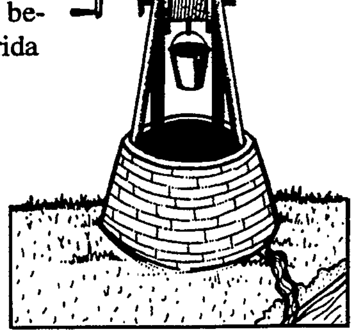
Water Reuse

Since 1970, Aurora, Colorado, has reused reclaimed domestic wastewater to irrigate the Aurora Hills Golf Course. Aurora uses an average of 100 million gallons per year of reclaimed wastewater pumped from the Sand Creek Wastewater Reclamation Facility to an onsight nonpotable water reservoir. In 1980, four city parks requiring an additional 50 million gallons of irrigation water per year were added to the reclaimed water system. In 1980, costs of the water reuse system, including debt service for the original filtration complex and transmission line but excluding irrigation pumping costs, averaged $0.43/1,000 gallons (1980 dollars) compared with $0.78/1,000 gallons for traditionally supplied water (USEPA, 1991a).

- The identification of wastewater sources that satisfy the water quality requirements.
- The determination of how the water can be transported to the new use (Brown and Caldwell, 1990).

Well Capping

Well capping is the capping of abandoned artesian wells whose rusted casings spill water in a constant flow into drainage ditches. In Seminole County, Florida, state hydrologists estimate that 1,500 abandoned artesian wells are discharging 54 Mgal/d. To put that in perspective, utilities in Seminole County pump less than 40 Mgal/d. The cost to plug such wells is about $750 (1990 dollars) per well. The state legislature has required that all such wells be capped beginning in 1993 (Florida Commission, 1990).



Abandoned wells in Seminole County, Florida, are discharging 54 Mgal/d.

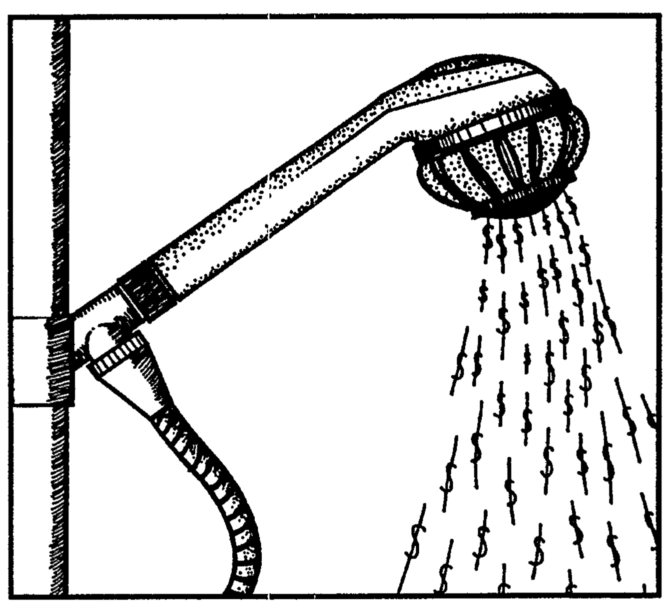
Planning and Management Practices

In addition to engineering practices, system operators can use several other practices to conserve water or improve water use efficiency.

Pricing

Information and education promoting conservation do not appear to be effective by themselves in achieving a conservation goal without at the same time imposing significant price increases to provide a financial incentive to conserve water (Martin and Kulakowski, 1991). Customers use less water when they have to pay more for it and use more when they know they can afford it. However, most people consider water to be a "free good" and are not willing to pay higher prices that reflect the true costs associated with the water delivered to their homes. Rate structures have the advantage of avoiding the costs of overt regulation, restrictions, and policing while retaining a greater degree of individual freedom of choice for water customers.

Overall charges for water service increased at an average compound rate of 7 percent per year during the 1980s—nearly double the rate of inflation (Russet and Woodcock, 1992). There is con-



Customers use less water when they have to pay more for it.

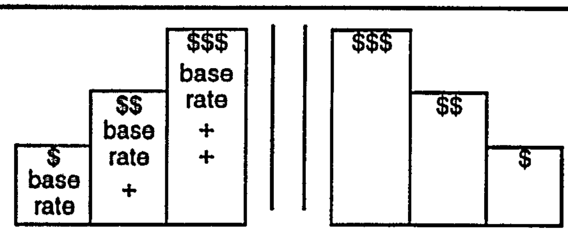
cern over "price gouging" due to increased water rates (Collinge, 1992). Some pricing has been objected to on the grounds that it can lead to a substantial excess of revenues over costs—an excess that might be inequitable and, in some states, unconstitutional (Collinge, 1992).

Water utility managers must establish and design water rates that meet revenue requirements and are fair and equitable to all customer classes in the water system. This task involves the following procedures:

- Determination of the water utility's total annual revenue requirements for the period for which the rates are to be in effect.
- Determination of service costs by allocation of the total annual revenue requirements to the basic water system cost components and distribution of these costs to the various customer classes in accordance with their service requirements.
- Design of water rates to recover the cost of service from each class of customer (Mui et al., 1991).

Several price rate structuring alternatives are available for water system operators.

Increasing Block Rate, or Tiered, Pricing. Increasing block rate, or tiered, pricing reduces water use by increasing per-unit charges for water as the amount used increases. For example, the first volume of water (block) used is charged a base rate, the second block is charged the base rate plus a surcharge, and the third block is charged the base rate plus a higher surcharge. It is necessary to increase real prices significantly to overcome the effects of conservation (Martin and Kulakowski, 1991).



Tiered pricing discourages water use.

Decreasing block rate pricing encourages water use.

For example, as the cost of water increased in Tucson, Arizona, residents used 33 percent less water between 1974 and 1980. A 10 percent increase in water rates provided about 3 percent more revenue while triggering a 7 percent reduction in use (Billings and Day, 1989). Using seasonal increasing block rate pricing during summer and winter months, to encourage year-round conservation, resulted in estimated water savings for the single-family residential class in Tucson of an average 2.23 Mgal/d during 1983-1986 (Cuthbert, 1989).

Decreasing Block Rate Pricing. Decreasing block rate prices reflect per-unit costs of production and delivery that go down as customers consume more water.

The monthly water use records of 101 customers were measured in a study of municipal water use in the city of Denton, Texas. Summer water use records from 1976 to 1980 during a decreasing block rate period were compared to summer use records from 1981 to 1985 during an increasing block rate period. It was found that the decreasing block rate scenario encouraged greater water use, whereas the increasing block rate scenario resulted in a reaction to the price increase and a corresponding decrease in water use (Nieswiadomy and Molina, 1989).

Time-of-Day Pricing. Time-of-day pricing charges users relatively higher prices during a utility's peak use periods. Because customers are sensitive to price increases, these charges curtail demand. Time-of-day pricing can cut generating capacity and reduce reliance on expensive secondary fuel sources (Sexton et al., 1989).

Water Surcharges. A water surcharge imposes a higher rate on excessive water use. The customer pays more money per gallon for water use that is considered higher-than-average.

Surcharges include unit surcharges, winter/summer ratios, and alternative seasonal rates. The *unit surcharge* method establishes a threshold level for excess consumption based on average daily per capita or per-household consumption. A surcharge is imposed for all water use above that threshold level. For the *winter/summer* ratio, metered water use during the winter period is compared to consumption during the corresponding summer period, and a higher rate or surcharge is imposed for water

Surcharges include winter/summer ratios and alternative seasonal rates.

consumption above the average winter use. Typically, an increase in usage of 14-20 percent occurs during the summer. Under an alternative *seasonal rate* structure, all water used during the summer or peak season is billed at a higher rate than that used during the other seasons. The increased rate is applied to all customers at all water-use levels (Schlette and Kemp, 1991).

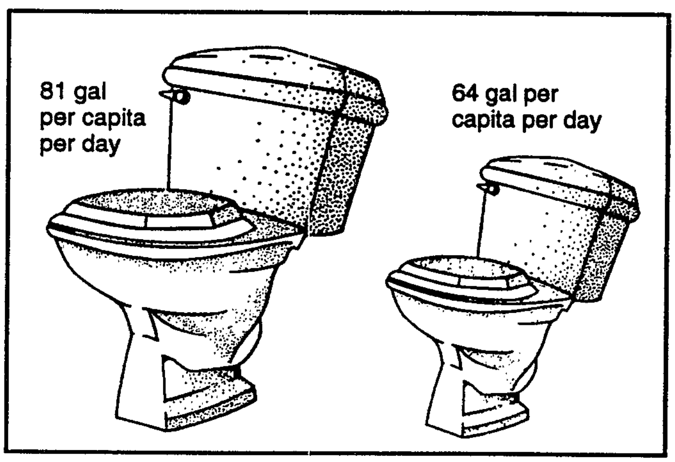
Retrofit Programs

Retrofit programs are another tool system operators can use to promote water use efficiency practices. Retrofitting involves the replacement of existing plumbing equipment with equipment that uses less water. The most successful water-saving fixtures are those which operate in the same manner as the fixtures they are replacing—for example, toilet tank inserts, shower flow restrictors, and low-flow showerheads. (For more information, refer to the practices for residential users.) As discussed previously, retrofit programs are permanent, one-time conservation measures that can be implemented with little or no additional cost over their lifetimes (Jensen, 1991).

A retrofit program can involve the use of education programs to let users know which fixtures are best, where to get them, and how to install them. System operators can also purchase water-efficient fixtures and resell them at cost to the users, but the most successful retrofit programs have been those in which the system operator purchases, distributes, and installs the fixtures (AWWA, n.d.).

Retrofit programs have been shown to be cost-effective and useful in conserving water in many cases. An apartment building in New England with 151 units was retrofitted with low-flow showerheads and faucet aerators at a cost of $1,074. As a result of the retrofit 1,725,000 gallons of water, $8,590 for energy, and $980 for water were saved in 1 year (AWWA, n.d.). In another retrofit program, the Lower Colorado River Authority installed low-flow showerheads and toilet dams in an apartment complex and public housing program in Marble Falls, Texas. Indoor per capita water use was reduced by 21 percent (from 81 to 64 gal/cap/day) in the apartment complex and was reduced 11 percent (from 102 to 91 gal/cap/day) in the public housing program (Jensen, 1991).

Current use of low-flow toilets throughout Texas could reduce the need to build new water and wastewater treatment plants by 15 percent, resulting in a savings of as much as $3.4 billion during the next 50 years. Residential water and sewer bills could also be reduced by as much as $200 million over the long term. The Texas Water Development Board estimates that the use of water-efficient plumbing fixtures should save a typical four-member household 55,800 gallons of water and $627 in reduced water and energy costs



The installation of low-flow showerheads and toilet dams in a Texas apartment complex reduced per capita water use by 21 percent.

per year. The Board estimates that the use of low-flow fixtures might reduce water use statewide by 805 Mgal/d by the year 2040 (Jensen, 1991).

Retrofit programs can be combined with water audit programs (discussed below) to further improve potential water savings.

Residential Water Audit Programs

Residential water audit programs involve sending trained water auditors to participating family homes, free of charge, to encourage water conservation efforts. Auditors visit participating homes to identify water conservation opportunities, such as repairing leaks and low-flow plumbing, and to recommend changes in water use practices to reduce home water use. The audit programs try to stretch existing water supplies by getting water users to use water more efficiently (Whitcomb, 1990). The largest percentage of indoor use comes from bathing and toilet flushing. Therefore, the bathroom is an ideal place for water system operators to focus water conservation efforts (Grisham and Fleming, 1989).

Residential Water Audit

In 1988 the Contra Costa Water District (CCWD) in California began a residential water audit program to reduce both indoor and outdoor water use. In 1989, the study year, indoor water use was reduced by the installation of low-flow shower heads (2.75 gpm at 80 psi) and toilet displacement bags (0.7 gal). Toilet and faucet leaks were also identified. Lawn sprinklers were checked for worn or nonworking parts to reduce outdoor water use. Auditors also tested and recommended changes in irrigation use coverage, provided a recommended irrigation schedule based on soil and lawn analysis and seasonal climatic conditions, and distributed a brass hose nozzle and educational material. The audit resulted in an indoor water savings of 8.9 gal per home per day (when 39.5 percent of the showers were retrofitted with low-flow showerheads), and an outdoor water savings of 39.1 gal per home per day for a total savings of 48.0 gal per home per day (Whitcomb, 1991).

Public Education

Public education programs can be used to inform the public about the basics of water use efficiency:

- How water is delivered to them.
- The costs of water service.
- Why water conservation is important.
- How they can participate in conservation efforts.

Public education is an essential component of a successful water conservation program. A num-

Public Education

Gallup, New Mexico, estimates that its water conservation program has reduced its per capita water use from 160 to 150 gal/cap/day. In 1983, Gallup and several other New Mexico communities participated in a public education program on water conservation coordinated by the governor's office and funded by ACTION, the federal volunteer service agency, and the U.S. Department of Energy. Grants were given to local governments to develop water conservation programs. About 42,500 water conservation kits containing brochures and water-saving devices were distributed. The Gallup project was estimated to have cost $1 per 1,000 gallons of water per person per year. It is estimated that if 43 percent of the flow restrictors distributed were installed, about 167 million gallons of water a year, or nearly 2 percent of the state's total 1985 urban and rural water withdrawals, are being saved (Grisham and Fleming, 1989).

The Department of 4-H/Youth, through Indiana's Purdue University Cooperative Extension Service, has produced a board game to educate children ages 9 to 12 about water trivia. "To the Last Drop" won a national award for educational materials from the Agricultural Communicators in Education organization in 1992 (Purdue University, 1992).

ber of tools can be used to educate the public: bill inserts, feature articles and announcements in the news media, workshops, booklets, posters and bumper stickers, and the distribution of water-saving devices. Public school education is also an important means for instilling water conservation awareness (Grisham and Fleming, 1989).

Another way to provide public information and education, as well as to collect real-world data on water conservation and use efficiency, is through the use of demonstration projects. In Tucson, Arizona, the Casa del Agua, a single-family home, has been used to demonstrate and study water conservation and reuse techniques and technologies. In 1985, the University of Arizona designed and retrofitted the Casa del Agua with water-conserving fixtures, a rainwater harvesting system, gray water reuse and storage systems, and drought-tolerant plants. Measurements of water use and water quality at the Casa del Agua have provided a useful collection of data for evaluating the possible benefits of conservation techniques and technologies in a residential home (Karpiscak et al., 1991).

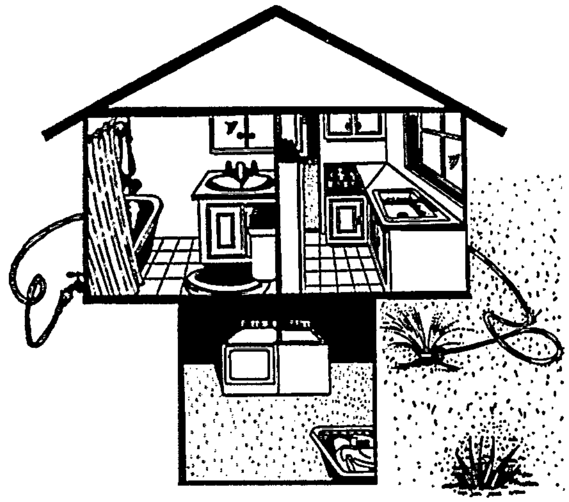
A study of water demand in the United States using American Water Works Association (AWWA) data indicated that water users are more sensitive to a change in price in the South and the West than in the other regions of the country. Public education appears to have reduced water usage in the West. A heightened awareness of water's scarcity might make educational programs more effective in the West than in the rest of the country (Nieswiadomy, 1992).

WAVE

WAVE (Water Alliances for Voluntary Efficiency) is a nonregulatory water-efficiency partnership created and supported by U.S. EPA. Its goal is to encourage U.S. hotels, motels, inns, or other lodging businesses to reduce water consumption while increasing efficiency, profitability, and competitiveness. Partnership is voluntary and members benefit from water and energy cost savings, enhanced public image, and the opportunity to improve operational effectiveness. EPA provides partners with marketing, technical, and public-recognition support services. Partners agree to endorse WAVE's concepts, survey water-use devices, appoint a WAVE implementation manager, install upgrades, design water-efficient facilities, and provide progress reports and program data to EPA. For more information, please contact: WAVE Program Director, U.S. EPA, 401 M Street, SW, Mail Stop 4204, Washington, DC 20460. Phone (202) 260-7288; fax (202) 260-1827 (USEPA,1994).

Water Wiser

The Water Efficiency Clearinghouse is a unique information source created to assist water professionals and other interested parties in locating current, comprehensive information on water efficiency topics. Water Wiser is a cooperative project between EPA and the American Water Works Association. The clearinghouse is designed to be the preeminent information resource for those who want to make sure our limited water resources are used wisely and efficiently. Water Wiser has an array of information services available to help plan, implement, and evaluate water efficiency programs and activities. Information services available include referrals, annotated bibliographies, literature searches, information packets, and fact sheets. Water Wiser can also be contacted by Internet. For access information, or to request any of the services listed above, call 1-800-559-9855 (AWWA, 1994).



Index of Water Efficiency

An index of water efficiency, or "W-Index," can be used as a device to evaluate residential water savings and as a way to motivate water users to adopt water-saving practices. A W-Index can serve as a measure of the effectiveness of water efficiency features in a home. The index provides a calculated numerical value for each dwelling unit, which is derived from the number and kind of water-saving features present, including indoor and outdoor water savers and water harvesting or recycling systems. Architects, builders, appraisers, homeowners, water suppliers, or water management agencies can use the W-Index as a basis for evaluating the water-saving capability of any particular single- or multi-family dwelling unit (DeCook et al., 1988).

Typically, an overall W-Index rating of W-50 would be considered fair, W-80 good, and W-110 excellent, based on a specific set of community water conservation goals (DeCook et al., 1988). The W-Index has been applied to the Casa del Agua, the Tucson, Arizona, water conservation demonstration home discussed in the preceding section. The Casa del Agua received a value of W-139. The index was applied to about 30 other homes in the Tucson area, with resulting values ranging from W-75 to W-100.

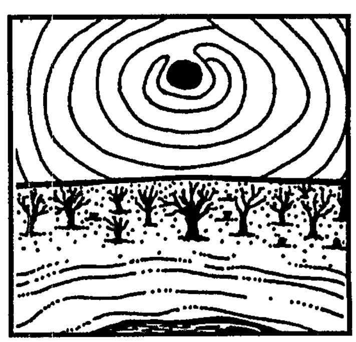
Planning for Resource Protection

Monitoring and managing land use and waste disposal practices around water supply sources can potentially reduce the need for new water supply development and keep water treatment costs to a minimum (Gollnitz, 1988). Adverse effects on a water supply source can be lessened through land use controls such as land preservation, nonregulatory and regulatory watershed programs, environmental assessment requirements, and zoning (Gollnitz, 1988). The protection of a water source by a utility can range from simple sanitary surveys of a watershed to the development and implementation of complex land use controls.

Water supply source protection should play an important role in the overall management of a municipal water utility. Contamination of a water source can result from point and nonpoint sources of pollution such as chemical spills, waste discharges, or the improper use and runoff of insecticides and herbicides. The contamination of a water supply source can result in the need to develop expensive treatment systems or to find new sources for water supply.

Drought Management Planning

When less rain falls than usual, there is less water to maintain normal soil moisture, stream flows, and reservoir levels and to recharge ground water. Falling levels of surface waters create unattractive areas of exposed shoreline and reduce the capacity of surface waters to dilute and carry municipal and industrial wastewater. Water quality often decreases as water quantity decreases, adversely affecting fish and wildlife habitats. In addition, dry conditions make trees more prone to insect damage and disease and increase the potential for grass and forest fires (TVA, n.d.).



A drought management plan should address a range of issues, from political and technical matters to public involvement. Managing a resource essential to people's welfare during disaster and dealing with the associated emotional, economic, and physical consequences makes drought management a very challenging task.

General Drought Management Components

1. Define the available resources: Water may be available from several sources to meet demands in time of drought.

2. Define the demand: The quantity, quality, and location requirements of all users must be defined.

3. Describe possible shortfalls in supply: Managing the resources to best accommodate the shortfall in meeting demand under a given drought event calls for sound preparation.

4. Describe the management measures for potential events: Define the adopted measures necessary in response to projected shortfalls for various drought events.

5. User and public involvement: it has been repeatedly proven that the success of drought management depends most on the understanding and support of the users and the public.

6. Securing legislation agreements, rules, and procedures: Any water management under conditions of shortage usually calls for new authority, rules, and procedures; for example, new legislation and specific legal agreements.

7. Drought management event plan: Any drought requires a specific set of management actions tailored to the specific event and a mechanism to forecast event dates (Frederiksen, 1992).

Chapter 4

Regional Approaches to Efficient Water Uses: Tales From the Trenches

This chapter presents a sampling of programs throughout the Nation that use one or more water conservation and use efficiency practices. Table 5 presents a summary of the practices used in each example program. It also provides a row to use in evaluating the water use efficiency program in your area.

It is important to note that the information in the table and in the examples is provided to illustrate the water savings that can be achieved by using a conservation and use efficiency practice or combining a mixture of practices. Many other practices and pro-

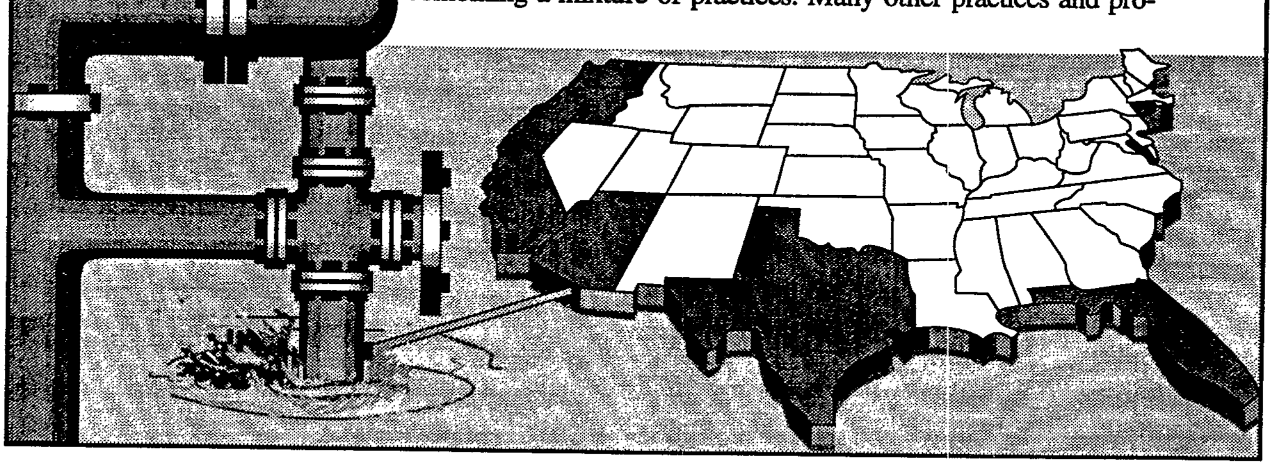


Table 5. Practices adopted by selected state, tribal, and city water use efficiency programs

	DEVELOPED WATER CONSERVATION PROGRAMS	PLUMBING CODE CHANGES	LOW-FLOW PLUMBING REQUIREMENTS	WATER USE RESTRICTIONS	IRRIGATION RESTRICTIONS	LANDSCAPE WATER MANAGEMENT PROGRAMS	XERISCAPE	EDUCATION	MEDIA CONSERVATION CAMPAIGN	WATER CONSERVATION AWARDS PROGRAMS	RATE STRUCTURING	RETROFIT	WATER CONSERVATION KIT DISTRIBUTION	LOW-FLOW FIXTURES REBATE PROGRAMS	RESIDENTIAL WATER AUDIT PROGRAMS	COMMERCIAL/INDUSTRIAL WATER AUDIT PROGRAMS	MUNICIPAL SYSTEM LEAK DETECTION AND REPAIR PROGRAM	HOME LEAK DETECTION AND REPAIR	METERING PROGRAMS	WATER USE DATA BASE	WATER REUSE PROGRAM	WATER RECYCLE PROGRAM	URBAN WATER MANAGEMENT PLANNING ASSISTANCE	INDUSTRIAL MANAGEMENT PLANNING ASSISTANCE	AGRICULTURAL MANAGEMENT PLANNING ASSISTANCE	FINANCIAL INCENTIVES PROGRAM
TAMPA	✦	✦	✦	✦	✦	✦	✦	✦			✦	✦		✦				✦								
SOUTH FL WMD	✦		✦	✦	✦		✦	✦	✦		✦						✦	✦			✦					
CALIFORNIA STATE	✦						✦	✦									✦	✦				✦	✦	✦	✦	
LOS ANGELES, CA	✦		✦			✦	✦	✦		✦	✦		✦	✦					✦							
SAN JOSE, CA	✦	✦						✦				✦		✦	✦	✦										✦
LOMPOC, CA	✦	✦	✦	✦	✦		✦	✦	✦			✦	✦	✦							✦					
CONNECTICUT	✦	✦						✦				✦	✦					✦								
NEW YORK, NY	✦							✦				✦	✦	✦	✦	✦	✦	✦	✦							
WASHINGTON, DC	✦	✦	✦					✦	✦		✦	✦					✦	✦		✦						
STILLAGUAMISH TRIBE	✦							✦				✦					✦	✦	✦							
TEXAS	✦	✦		✦				✦			✦	✦					✦		✦							
OREGON	✦																									
ARIZONA	✦																									
PHOENIX, AZ	✦	✦			✦			✦				✦	✦		✦											
TUCSON, AZ	✦	✦						✦			✦															
YOUR LOCATION																										

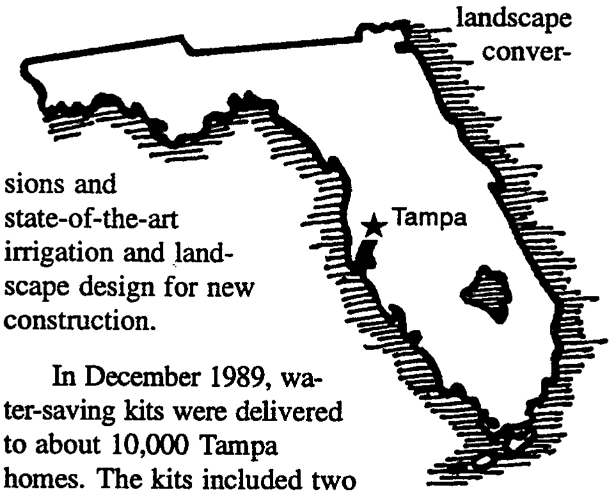
grams could be cited as well (such as the State of Massachusetts Water Resources Authority, and the City of Denver, Colorado; City of Austin, Texas; Portland, Oregon; and the Metropolitan Water District of Southern California) Also note that the information presented is dated material obtained from published reports and might have changed since the date of original publication.

Florida

Tampa

Since 1989, Tampa's water efficiency program has included code changes, revised rate structures, retrofit, promotion of xeriscape landscaping, and education. Within the first 9 months, consumption was reduced from 84.6 million gallons to 72.5 million gallons during the dry months of March through June, a 15-18 percent reduction in demand. The average reduction for the year was 7 percent.

Tampa has adopted an increasing-block rate structure, irrigation restrictions, landscape codes, and ultra-low-volume plumbing requirements. Voluntary xeriscape programs advocate corporate landscape conversions and state-of-the-art irrigation and landscape design for new construction.



In December 1989, water-saving kits were delivered to about 10,000 Tampa homes. The kits included two toilet tank dams, two low-flow showerheads, two lavatory faucet aerators, some Teflon tape, a pamphlet on finding and fixing leaks with a general "water-saving tips" card, an installation instruction folder (with a letter from the mayor encouraging participation, and instructions in both Spanish and English), a window display card, and leak detection dye tablets. These materials were packed in a clear plastic bag and hung on the doorknobs of residences. Ninety-four percent of homeowners receiving the kits installed the devices. The kits were estimated to save 7-10 gallons of water per person per day. Tampa estimates that when all the homes in Tampa are similarly retrofitted, more than 2.1 million gallons of water per day will be saved.

Educational efforts in Tampa focus on schools. A number of contests have been conducted. Winning poster and limerick entries are compiled into a water conservation calendar, which is then distributed to the general public.

Additional efforts in Tampa include a pilot awareness campaign, an expanded retrofit program, toilet-replacement incentive projects including a rebate program, implementation of water checkups for large residential water users, and enhanced in-school curriculum-based education (RMI, 1991).

South Florida Water Management District

In 1992, the South Florida Water Management District (SFWMD, which includes Palm Beach, Dade County, Florida) joined the St. Johns River Water Management District (in northeast Florida) and Southwest Florida Water Management District (Tampa, Sarasota, etc.) in sponsoring a statewide mass-media conservation campaign that urges residents to conserve water and use it wisely. The campaign features public service spots that urge residents to use xeriscaping and offers other water-saving tips. Educational brochures and how-to guides, an informative video on how to xeriscape a typical Florida yard, and a quarterly newsletter were all produced to support this educational effort.

The SFWMD's Six-Point Conservation Policy appeals to local governments to adopt conservation measures. The policy advocates the adoption of local xeriscape ordinances, leak detection programs, ordinances that encourage the residential and business use of low-volume plumbing, rate structures that reward conservation and reduced use, comprehensive public education programs, and daytime irrigation bans.

In other programs, the SFWMD offers technical assistance to cities and counties in implementing rain switch ordinances (which require automatic sprinklers to be turned off during rain storms) and water reuse systems, and the district is supporting a statewide Compost Utilization Project. The SFWMD is also a sponsoring member of the state's Xeriscape/Water Wise Council Steering Committee, formed to help implement the state's Xeriscape Law, passed in 1991.

Through conservation partnerships formed in 1992, the SFWMD assisted the Dade, Broward, Palm Beach, and Lee county governments in developing daytime irrigation ordinances, and it is urging other counties to adopt daytime irrigation bans (Kirchhoff and Nicholas, 1993).

California

State of California

The State Department of Water Resources provides general information and offers technical assistance with water conservation practices to all local water agencies in California.

Agricultural irrigation is the largest water use problem in California, and the Department focuses on agricultural as well as urban water use efficiency programs. The urban program includes the following practices: leak detection, water-efficient landscaping, conservation information, public education, urban water management planning assistance, industrial water conservation planning, and water recycling. The agricultural program includes the following practices: drainage reduction, mobile laboratory program for on-farm irrigation system evaluations, the California Irrigation Management Information System (CIMIS), and agricultural water management planning assistance (Keith Watkins, California State Department of Water Resources, Office of Water Conservation, February 9, 1994, personal communication).

Los Angeles

The Los Angeles Department of Water and Power has implemented a comprehensive water efficiency plan to address water use by individual households, businesses, and industries. To limit outdoor water use, L.A. offers a landscape water management program, a water conservation garden contest, an annual spring garden exposition, demonstration gardens, weather network stations, a residential irrigation pilot program, a large-turf water curtailment program, xeriscape requirements for new construction, and production and distribution of lawn-watering guides.

L.A. has water conservation advisory committees, business and industry bulletins and brochures, a free meter loan program, a school incentive program, and an annual business and industry symposium offering awards for excellence in water management. The city also coordinates various conservation efforts with other county and state water agencies.

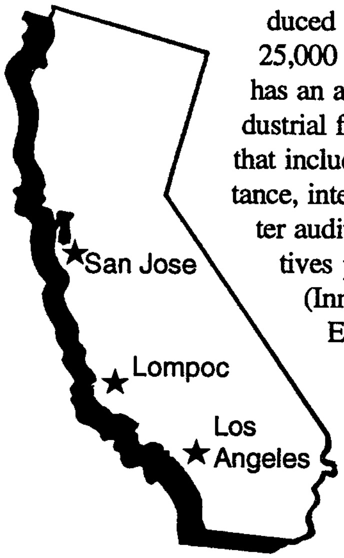
L.A.'s residential program includes an ultra low-flush toilet rebate program, home water surveys, and low-interest conservation loans. The educational agenda includes advertising, a water awareness month, water inserts sent out with water bills, exhibits, a speaker's bureau, and school education programs.

A city ordinance mandates the installation of low-flow showerheads (3.0 gallons per minute or less) and toilet tank displacement devices. These fixtures are available free to residential customers; there is a charge to commercial users. The L.A. Department of Water and Power has spent $5 million (1990 dollars) thus far on the purchase and distribution of 1.3 million showerheads and 1.8 million toilet bags. The program resulted in a 4 percent reduction in water consumption between 1987 and 1990.

L.A. has also adopted a seasonal pricing structure under which water is priced at a higher rate during the summer months. The city hopes to limit the annual growth in sewage flows to 7 Mgal/d and to reduce overall water consumption by 10 percent by 1995 and 15 percent by the year 2000 (RMI, 1991).

City of San Jose

In 1986, the City of San Jose Office of Environmental Management (OEM) set a 10-year goal of reducing the City's wastewater flow by 10 percent, a reduction of 12 Mgal/d. The implementation of plumbing codes and retrofit programs each re-



duced flows by more than 25,000 gpd in 1991. OEM has an active commercial/industrial flow reduction program that includes technical assistance, integrated energy and water audits, a financial incentives program, I.D.E.A.S. (Innovative Design and Energy Analysis Service program) standards for new commercial and industrial building, and do-it-yourself audit guides (JMM Consulting, 1991).

City of Lompoc

In January 1990, the City of Lompoc, California, declared a water shortage and initiated a voluntary conservation program. The program achieved a 14.4 percent cumulative reduction for 1990.

The Lompoc city staff conducts a public information program consisting of conservation brochures, displays, the use of local communications media, and classes dealing with water-saving irrigation methods and drought-tolerant planting methods. The city provides water conservation kits (free to low-income households and $5.00 to all other residents), which include two low-flow shower-heads, two toilet tank dams, two toilet leak detection tablets, two faucet aerators, and an installation brochure. The annual operating cost of Lompoc's program is about $120,000 (1990 dollars).

The 1990 Lompoc City Ordinance 1312(90) declares a water shortage in the city and establishes various restrictions and prohibitions on the use of water, including the following: turf watering between the hours of 10:00 a.m. and 4:00 p.m., the use of potable water for washing hard surface areas such as driveways and sidewalks, allowing water to flow from plumbing breaks or leaks for more than 8 hours, washing vehicles with hoses that do not have a positive shut-off nozzle, and serving water to restaurant patrons before they request it. In addition, the water shortage ordinance establishes the mandatory use of ultra-low-flush toilets and urinals in all new commercial, industrial, and public buildings.

The 1990 Lompoc City Ordinance 1319(90) provides for the use of gray water (used water from clothes washers, bathtubs, showers, and bathroom sinks) for irrigation of fruit trees, ground cover, and ornamental trees and shrubs, but not for irrigating vegetable gardens and lawns or washing off hard surfaces. It also provides for the use of reclaimed water for dust control and compaction at construction sites, under limited conditions.

The 1990 Lompoc City Ordinance 1334(90) establishes the one-to-one "zero impact" retrofit condition for new development in the city. Under this ordinance a developer has the option to either (1) carry out a retrofit program of existing housing, resulting in a zero projected net increase in water consumption resulting from the new construction or (2) pay an "in-lieu" fee to the city. Funds from such fees are then directed to the city's retrofit rebate program.

The 1990 Lompoc City Ordinance 4000(90) sets guidelines for the city's retrofit rebate program. Under this program, revenues from the "in-lieu" fees are used to fund a city-run retrofit/rebate program for showerheads, kitchen and bathroom sinks, and toilets (NEOS Corporation, 1990).

Connecticut

Since October 1, 1990, Connecticut law has required standards for water-efficient fixtures manufactured and sold in the state. Showerheads must use less than 2.5 gallons per minute; urinals, 1.0 gallon per flush; faucets, 2.5 gallons per minute; and toilets, 1.6 gallons per flush. The state has also organized a retrofit program that requires all water distributors to give away free water-efficiency kits. Each kit contains one low-flow showerhead, two faucet aerators, one pair of toilet tank dams, one package of toilet leak detection tablets, and written information. The cost of the kits, $6-$7 each, is absorbed by water users through their rates (RMI, 1991).

New York City

New York City's water efficiency program is a comprehensive one. The program includes a survey of all 33.6 million feet of water mains with computerized sonar leak detection equipment. Areas of the city that are served by wastewater treatment plants are inspected by sonar once every 9 months. All other areas are inspected once every 3 years. The New York City Department of Housing, Preservation, and Development and the New York City Department of Environmental Protection test the benefits of retrofitting with water-efficient fixtures on city buildings.

New York City offers free water efficiency surveys to homeowners. City inspectors check for leaking plumbing, provide water conservation tips, offer advice on retrofitting with water-efficient fixtures, and distribute two free faucet aerators and two free low-flow showerheads. Landlords are notified of leaks and given 3 days to repair them and have the repair confirmed. New York City has made over 60,000 of these inspections, eliminating more than 4 Mgal/d in leaks (RMI, 1991).

A Toilet Rebate Program was initiated on August 1, 1994. Residents can file an application for a rebate if they have had a new water-conserving toilet installed by a New York City licensed plumbing company.

New York City has also installed magnetic locking hydrant caps to deter people from turning on hydrants in the summer. The new locked hydrants not only conserve water, but also reduce the amount of urban runoff going into the sewer systems.

Under an Advanced Flow Monitoring Program, New York City has installed flow monitoring devices in large sewer mains that lead to wastewater treatment plants operating at high capacity. The program helps detect patterns of new leaks and where those leaks originated.

By 1997, all residential and commercial buildings will be metered to follow consumption rates. To date, about two-thirds of all one- or two-family homes and about 15 percent of apartment buildings are metered. (Warren Leibold, New York Department of Environmental Protection, December 29, 1994, personal communication.)

Washington, DC

High growth rates in Washington, DC, have resulted in a need to find solutions to the resulting increased flows to the District's wastewater treatment plant. A water conservation program has been developed by the District of Columbia Department of Public Works to reduce the rate of flow to the Blue Plains Wastewater Treatment Plant, a regional facility servicing Washington and its suburbs.

In a 1985 agreement, users of the Blue Plains facility agreed to limit the flow of wastewater to the facility to 6.5 cubic meters per second (m^3/s) or 148 Mgal/d by January 1, 1996. In 1991, the flow to the facility was approximately 7.2 m^3/s, or 163 Mgal/d. It has been determined that if flows to the facility are not reduced to those set forth in the agreement, an increase in the treatment capacity of the facility will be necessary.

Studies conducted in the metropolitan area indicate that as much as 1.3 to 2.6 m^3/s, or 30 to 60 Mgal/d, is wasted primarily because of careless use and defective plumbing systems in older buildings.

Washington, DC, officials determined that the development of a water conservation program would be the most cost-effective way to address the wastewater treatment problem. The water conservation program developed by the District of Columbia Department of Public Works includes public information and education, a comprehensive database on water use, amendments to the plumbing code, guidelines for retrofitting and plumbing repair, and possible restructuring of water and sewer rates. The education program informs water users of the benefits of water conservation and includes a media campaign, the development of a water conservation handbook and video, the use of coloring books on water conservation for school children, and plumbing clinics and training programs. The revisions to the plumbing code require the use of water-saving fixtures in new construction and substantial renovation projects. The water consumption database will provide information for comparing water flow to sewer flows, identifying water losses, and developing conservation strategies that are practical and effective.

It was estimated in 1991 that the water conservation program for Washington, DC, would cost the district approximately $8 million over a 5-year period. The conservation program is considered to be cost-effective, however, because wasted water in the Blue Plains service area is estimated to cost the district's water and sewer customers millions of dollars per year (Padmanabha, 1991).

Stillaguamish Tribe in Arlington, Washington

The Stillaguamish Tribe in Arlington, Washington, developed a water conservation program to help reduce problems associated with a failing community septic tank and drainfield system. The tribal trust consists of a 30-home development on a 20-acre parcel of land that is serviced by five separate drainfield areas and two community drinking water wells. Within the first 5 years following the construction of the development, two of the five drainfields servicing the project have had to be replaced due to failure.

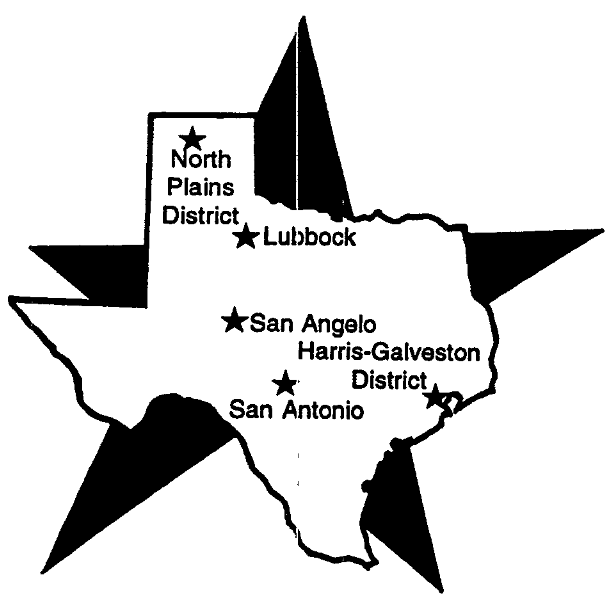
A water conservation program was developed, with a $14,000 EPA grant, to reduce the community use of drinking water from the tribe's system. The reduction in water use would result in a reduction in the amount of water loaded into the septic tank drainfield system.

In 1991, the conservation program arranged for the retrofitting of standard toilets with ultra-low-flush toilets, the installation of flow restriction devices on all faucets, and the development and implementation of a water conservation education program for the homeowners in the housing development. In 1992, nonfunctioning water meters were replaced so that individual water usage could be measured and leaks within the water distribution system could be identified.

The water conservation program has resulted in a reduction in the average community water use from 250,000 gallons per month to 200,000 gallons per month. In the first 9 months following the adoption of the conservation program, water usage dropped approximately 35 percent per home, resulting in a community water savings of over one million gallons. Operation and maintenance costs for the two water supply wells have dropped as a result of the reduction in water demand, and surfacing septage in the tribe's drainfields has not been a problem since adoption of the conservation program (Eddy, 1993).

Texas

House Bill No. 2, passed by the Texas legislature in 1985, is a comprehensive water conservation package designed to implement sections of the Texas Water Plan. Two constitutional amendments were contained in the conservation package, one that increased the Water Development Fund by $980 million and another that created the Agricultural Water Conservation Program. Political subdivisions within the state are now required to submit a water conservation plan to the Texas Water Development Board when they apply for financial assistance from the Water Development and Water Assistance Funds. Since the passage of House Bill No. 2, 21 new Underground Water Conservation Districts have been delineated, most of which are located near the City of San Angelo and the City of San Antonio, which relies exclusively on the Edwards Aquifer for its water supply.



Schoolmaster and Fries, 1990

Applicants for water supply loans are required to develop a water conservation plan and adopt a water conservation program that can include the following: restrictions on discretionary water use, water-saving plumbing code standards for new construction, retrofit programs for existing structures, education programs, universal metering, conservation-orientated water rate programs, drought contingency plans, and distribution system leak detection and repair. The requirement for an approved water conservation plan can be waived by the Water Development Board if an emergency exists, if the amount of the assistance is less than $500,000, or if the applicant can demonstrate that the plan is not necessary to promote conservation or conservation measures.

As of 1990, the Texas Water Development Board had approved water conservation plans for 165 political subdivisions in the state, many of which are located in Harris, Galveston, and Brazoria Counties. A pilot program was also set up prior to full implementation of the Agricultural Water Conservation Program. As of 1990, the Program had distributed $8,065,000 in low-interest loans to farmers for the purchase of water-efficient irrigation equipment. The single most expensive purchase was a $27,102 irrigation demonstration system for the North Plains Underground Water Conservation District (Schoolmaster and Fries, 1990).

Oregon

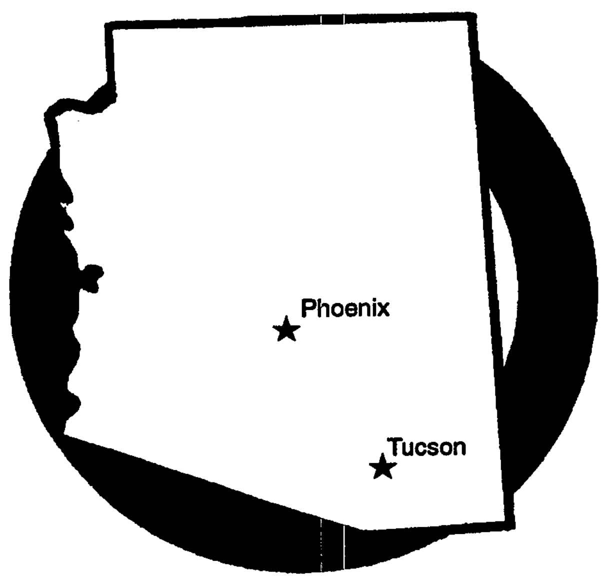
In December 1990, the State of Oregon adopted a water conservation policy that is implemented through conservation planning requirements for water suppliers and major water users, subbasin water planning at the local level, and extensive state assistance and support for implementation. The state also passed legislation to facilitate water sales and the lease of conserved water, but the transfers are taxed for a set-aside of water for instream flows rather than as a complete reallocation to another private party. In 1991 the state Water Resource Commission was also considering incorporating the requirement for efficiency standards and conservation practices into its operating definition of beneficial use for water allocation decisions (Dyballa and Connelly, 1991).

Arizona

In Arizona, public water suppliers located in areas where ground water withdrawals exceed recharge capacity are required to limit water consumption to state-established maximum water use rates. The water use rates are expressed in gallons per capita per day. Water suppliers are required to negotiate a water conservation plan that meets the state's targeted rates if they do not achieve established rate limits (Dyballa and Connelly, 1991).

Phoenix has implemented a conservation program to meet state-established ground water limits. The elements of the program include an education program, residential audit and retrofit programs, a mail order retrofit program, limits on turf irrigation, low-flow plumbing standards, and landscape requirements for large new buildings Dyballa and Connelly, 1991). The implementation of the water conservation program in Phoenix has resulted in a reduction in water use from 267 gal/cap/day in 1980 to 234 gal/cap/day in 1990.

The City of Tucson has also implemented a water conservation program that has resulted in large reductions in peak water demand. The elements of Tucson's program include public information and education, an increasing block rate price structure, and the use of water-saving plumbing fixtures.



Looking Ahead

Water is a resource that we often take for granted. We watch the rain fall or stand on the bank of a river and assume that our water needs will be taken care of—that water is a "free good" readily available to all. But a closer look reveals that it's not that simple. In many dry areas, water is a very limited resource; in other areas, water is being contaminated by various sources of pollution.

Now that nonpoint source (NPS) pollution has been recognized as a major contributor to declining water quality, the search is on for ways to eliminate or reduce this type of pollution. This document proposes one important approach not usually considered to reduce NPS pollution—reducing the quantity of water used. Using less water can reduce:

- On-site disposal system failures.
- Polluted runoff from irrigated agricultural and urban lands.
- The need for additional reservoir capacity and associated habitat alterations.
- Surface water withdrawals or diversions that result in degraded habitat and wetlands.

Water use efficiency has other benefits, too, such as saving money. For example, a leak caused by a faulty flush valve in a toilet tank can waste as much as 10 gallons of water an hour, costing $100 per year at $1.20/1,000 gallons.

More than 40 states now have some type of water conservation program, and more than 80 percent of water utility customers are willing to use some form of water conservation measure. The groundwork has already been laid for new and expanded programs to encourage water use efficiency. A number of practices, programs, and strategies described in this document can be implemented now. Some involve engineering practices based on modifications of plumbing, fixtures, or operating procedures. Others involve behavioral changes in water use habits. They range from the very simple (a dam in the toilet tank or a new hose nozzle) to the complex (the installation of multiple submeters in an apartment building).

From coast to coast—from the tribal trust homes of the Stillaguamish Tribe in Washington State to the water mains beneath the City of New York—water conservation and use efficiency practices are saving water and reducing nonpoint source pollution.

What's being done to conserve this precious resource where you live? And what more can you and others do?

Glossary

Agricultural irrigation: Water distribution systems and practices in agriculture (Kromm and White, 1990).

Air heat exchange: Cooling method, involving no water loss, during which a fan blows air past finned tubes carrying recirculating cooling water (Brown and Caldwell, 1990).

Block-rate pricing: Method of charging on the basis of the volume of water used.

Center pivot system: Method of agricultural irrigation consisting of a single sprinkler lateral with one end anchored to a fixed pivot structure and the other end continuously moving around the pivot while applying water (ASAE, 1980).

Chiseling of compacted soils: Loosening the soil, without inverting and with a minimum of mixing of the surface soil, to shatter restrictive layers below the normal plow depth that inhibit water and air movement or root development (Virginia State Water Control Board, 1979).

Closed loop cooling tower: Water-conserving cooling tower system in which water used for cooling is recycled through a piping system that cools the water; the water is cooled as air exchanges heat with the pipes (Brown and Caldwell, 1990).

Continuous flow system: The continuous use, by an industry, of deionized water to remove contaminants from products and equipment (Brown and Caldwell, 1990).

Cooling tower: Water-conserving cooling device in which cooling water loses heat when a portion of it is evaporated (Brown and Caldwell, 1990).

Cooling tower makeup: Water added to the recirculating cooling tower water stream to compensate for water evaporation losses (Brown and Caldwell, 1990).

Cooling water: Water typically used to cool heat-generating equipment or to condense gases in a thermodynamic cycle (Brown and Caldwell, 1990).

Cooling water blowdown: Procedure used to reduce total dissolved solids by removing a portion of poor-quality recirculating water (Brown and Caldwell, 1990).

Cooling water drift: Unevaporated water carried out of a cooling tower by the airflow; it has the same composition as the recirculating water (Brown and Caldwell, 1990).

Cooling water evaporation: Cooling water recycling approach in which water loses heat when a portion of it is evaporated (Brown and Caldwell, 1990).

Decreasing block rate: Pricing that reflects per-unit costs of production and delivery that go down as customers consume more water (Nieswiadomy and Molina, 1989).

Deionized water: Common industrial water used to remove contaminants from products and equipment (Brown and Caldwell, 1990).

Drop tubes: Devices that can be added to a center pivot system to achieve greater efficiency in agricultural irrigation (Kromm and White, 1990).

Dry cooling: Cooling-down process using steam, to eliminate the loss of water (Strauss, 1991).

Effluent: Wastewater, treated or untreated, that flows out of a treatment plant, sewer, or industrial outfall.

Faucet aerator: Device that can be installed in a sink to reduce water use (Jensen, 1991).

Furrow diking: Water-saving agricultural irrigation practice in which a long, narrow groove or trench is made in the earth by a plow. The dike is usually placed at one end of the field to collect runoff. (Kromm and White, 1990).

Gray water: Domestic wastewater composed of washwater from kitchen sinks, bathroom sinks and tubs, clothes washers, and laundry tubs (USEPA, 1989).

Ground water recharge: The use of reclaimed wastewater, by surface spreading or direct injection, to prevent saltwater intrusion into freshwater aquifers, to store the reclaimed water for future use, to control or prevent ground subsidence, and to augment nonpotable or potable ground water aquifers (USEPA, 1991a).

Increasing block rate: Pricing that reduces water use by structuring water rates to increase per-unit charges as the amount used increases (Martin and Kulakowski, 1991).

Instream flow: The amount of flow required to sustain stream values, including fish, wildlife, and recreation (USDOI, 1992).

Intermittent flow system: Alternating use, by an industry, of deionized water to remove contaminants from products and equipment (Brown and Caldwell, 1990).

Irrigation districts: Special units of local government that control the bulk of surface water supplies in the West (Smith and Vaughan, 1988).

Irrigation field practices: Techniques that keep water in the field, more efficiently distribute water across the field, or encourage the retention of soil moisture (Kromm and White, 1990).

Irrigation management strategies: Strategies to monitor soil and water conditions and collect information that helps in making decisions about scheduling application or improving the efficiency of the irrigation system (Kromm and White, 1990).

Irrigation scheduling: Careful choice of irrigation application rates and timing to help irrigators maintain yields with less water (Bosch and Ross, 1990).

Irrigation system modification: An addition to or an alteration of an existing irrigation system or the adoption of a new one (Kromm and White, 1990).

Landscape irrigation: Water conservation through landscaping that uses plants that need little water, thereby saving labor and fertilizer as well as water (Grisham and Fleming, 1989).

Leak detection: Systematic method of using listening equipment to survey the distribution system, identify leak sounds, and pinpoint the exact locations of hidden underground leaks (RMI, 1991).

Low-flow plumbing: Plumbing equipment that uses less water than was considered standard prior to January 1, 1994 (NAPHCC, 1992).

Low-flow showerhead: A showerhead that requires 2.5 gallons of water per minute or less, as compared to the 4.5 gallons of water required by most older standard showerheads (Jensen, 1991).

Low-flush toilet: A toilet that requires 1.6 gallons of water per flush or less, as compared to the 3.5-5 gallons of water required to flush most older standard toilets (Pearson, 1993).

Metering: Use of metering equipment that can provide essential data for charging fees based on actual customer use (Brown and Caldwell, 1990).

Monitoring of water: Monitoring of water use by an industry, using metering for example, to provide baseline information on quantities of overall company water use, the seasonal and hourly patterns of water use, and the quantities and quality of water use in individual processes (Brown and Caldwell, 1990).

Neutron probe: Type of probe used to monitor soil moisture conditions to help determine when water should by applied (Bosch and Ross, 1990).

Ozonation: A new technology using a form of oxygen, instead of chemicals, to treat cooling water (Brown and Caldwell, 1990).

Peak/off-peak rates: Rates charged in accordance with the most and least popular hours of water use during the day (Sexton et al., 1989).

Plenum flushes: Rinsing procedure that discharges deionized water from the rim of a flowing bath to remove contaminants from the sides and bottom of the bath (Brown and Caldwell, 1990).

Potable water: Water that is safe for drinking (USEPA, 1992).

Price gouging: Excessive water rate increases that are unfair to water customers (Collinge, 1992).

Pricing/rate structure: System used by water utility managers to charge customers for water usage (Collinge, 1992).

Recirculating cooling water: Recycling cooling water to greatly reduce water use by using the same water to perform several cooling operations (Brown and Caldwell, 1990).

Reclaimed water: Wastewater that is treated and reused to supplement water supplies (USEPA, 1991a).

Resistance block: Type of soil moisture probe used to monitor soil moisture conditions to help determine when water should be applied (Bosch and Ross, 1990).

Retrofit: Replacement of existing equipment with equipment that uses less water (Jensen, 1991).

Reverse osmosis: Common process used to produce deionized water from municipal water (Brown and Caldwell, 1990).

Rinsewater: Water used to remove debris and contaminants from products and equipment (Brown and Caldwell, 1990).

Rinse sink: Apparatus used to remove debris and contaminants from products and equipment (Brown and Caldwell, 1990).

Seasonal rate structure: Rate structure that bills all water consumed during the summer or peak season at a higher rate than during the other seasons (Schlette and Kemp, 1991).

Secondary treatment: The second step in most publicly owned waste treatment systems, which removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment (USEPA, 1989).

Secondary wastewater treatment plant: A facility that reduces pollutants and suspended solids to a greater level than that achieved by a primary treatment plant; the water goes through additional treatment processes, producing "cleaner" wastewater.

Source protection: Protection of a water source by a small utility, ranging from simple sanitary surveys of a watershed to the development and implementation of complex land use controls, in an effort to avoid water contamination (Gollnitz, 1988).

Submetering: Use of separate meters to indicate individual water use in apartments, condominiums, and trailer homes, while the entire complex of units continues to be metered by the main supplier (Rathnau, 1991).

Surge irrigation: The intermittent application of water to irrigation pathways. This method pulses water down the furrow and creates more uniform irrigation (Jalali-Farahani et al., 1993).

Tailwater recovery system: System modification to achieve greater efficiency in agricultural irrigation by collecting runoff for reuse in irrigation (Kromm and White, 1990).

Tensiometer: Type of soil moisture probe used to monitor soil moisture conditions to help determine when water should by applied (Bosch and Ross, 1990).

Threshold level: Level established as the average rate of water use (Schlette and Kemp, 1991).

Tiered pricing: Increasing block-rate pricing (Martin and Kulakowski, 1991).

Time-of-day pricing: Pricing that charges users relatively higher prices during utilities' peak use periods (Sexton et al., 1989).

Toilet displacement device: Object placed in a toilet tank to reduce the amount of water used per flush; for example, weighted plastic jugs filled with water or toilet dams that hold back a reservoir of water when the toilet is flushing (USEPA, 1991b).

Unit surcharge: A surcharge imposed for all water use above a threshold level for excess consumption established based on average per capita or per-household consumption (Pearson, 1993).

Utility: Public water service provider (Habibian, 1992).

W-Index: An index of water efficiency used as a device for evaluating residential water savings and as a management tool to motivate water-saving practices. The index provides a calculated numerical value for each dwelling unit, derived from the number and kind of water-saving features present, including indoor and outdoor water savers and water harvesting or recycling systems (DeCook et al., 1988).

Wafer fabrication rinse sink: Apparatus used during manufacturing to rinse debris and contamination from the circular configuration of semiconductor chips (Brown and Caldwell, 1990).

Wastewater: Spent or used water from individual homes, a community, a farm, or an industry that contains dissolved or suspended matter.

Wastewater treatment plant: A facility with an engineered system designed to remove pollutants, such as phosphorus and nitrogen, from municipal and industrial wastewater for discharge into surface waters.

Water audit: Program involving sending trained water auditors to participating family homes, free of charge, to identify water conservation opportunities such as repairing leaks and installing low-flow plumbing and to recommend changes in water use practices to reduce home water use.

Water conservation: Activities designed to reduce the demand for water, improve efficiency in use, and reduce losses and waste of water (Beecher and Laubach, 1989).

Water recycling: Reuse of water for the same application for which it was originally used (Brown and Caldwell, 1990).

Water reuse: Using wastewater or reclaimed water from one application for another application. The deliberate use of reclaimed water or wastewater must be in compliance with applicable rules for a beneficial purpose (landscape irrigation, agricultural irrigation, aesthetic uses, ground water recharge, industrial uses, and fire protection) (USEPA, 1991a).

Water surcharge: Imposition of a higher rate on excessive water use (Schlette and Kemp, 1991).

Water use efficiency: Employing water-saving practices to reduce costs and to slow the depletion of the water supply to ensure future water availability (Kromm and White, 1990).

Well capping: Capping of abandoned artesian wells whose rusted casings spill water in a constant flow into drainage ditches (Florida commission, 1990).

Winter/summer ratio: Comparison of metered water use during the winter period to consumption during the corresponding summer period. A higher rate or surcharge is imposed for water consumption above the average winter use (Schlette and Kemp, 1991).

Xeriscape landscaping: An innovative, comprehensive approach to pollution prevention and water use efficiency that incorporates all of the following: planning and design, soil analysis, appropriate plant selection, practical turf areas, efficient irrigation, use of mulches, and appropriate maintenance (Welsh et al., 1993).

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